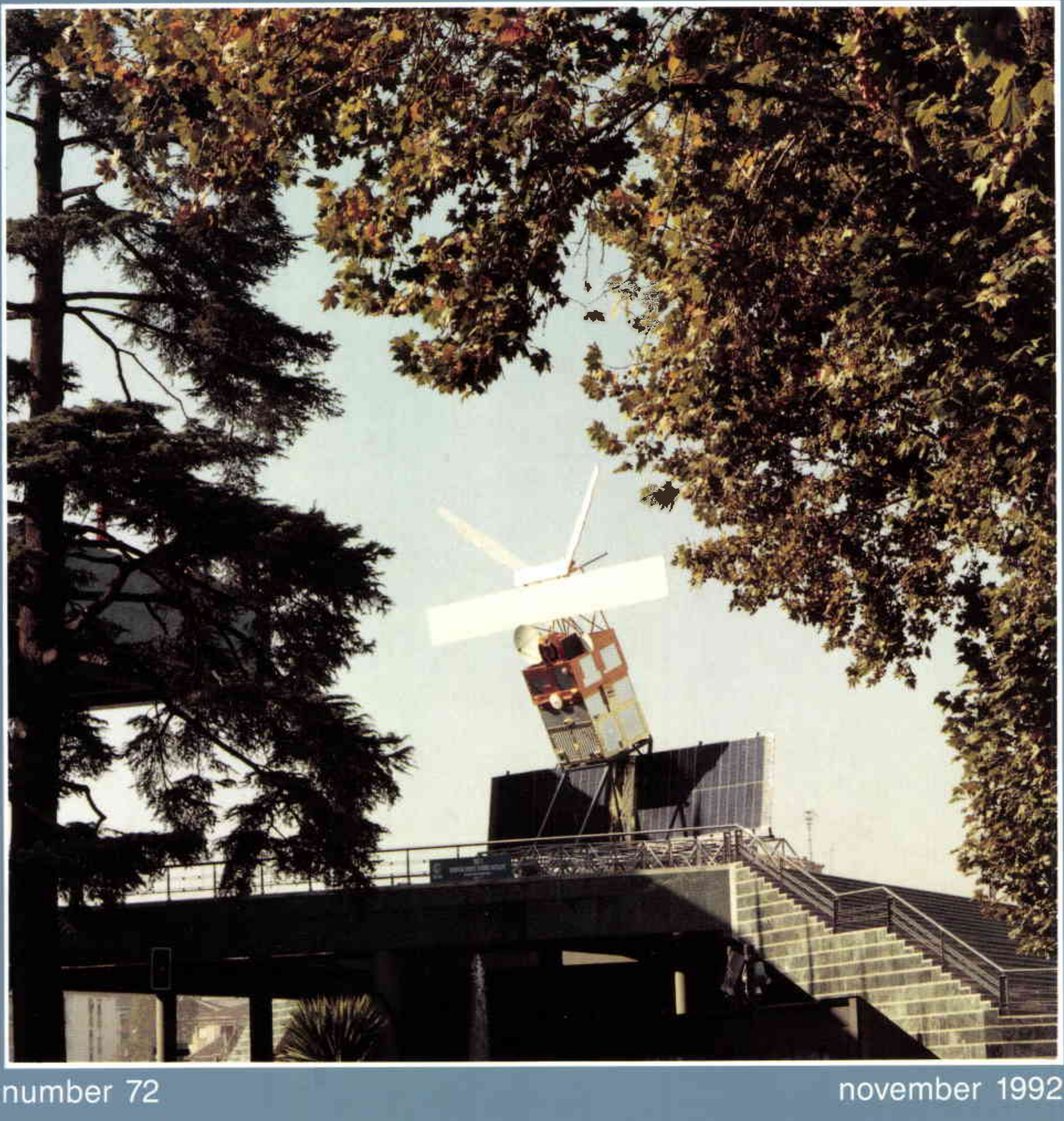
european space agency

esa bulletin

agence spatiale européenne



number 72 november 1992

european space agency

The European Space Agency was formed out of, and took over the rights and obligations of, the two earlier European Space Organisations: the European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). The Member States are Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. Finland is an Associate Member of the Agency. Canada is a Cooperating State.

In the words of the Convention: The purpose of the Agency shall be to provide for and to promote, for exclusively peaceful purposes, co-operation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems.

(a) by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
(b) by elaborating and implementing activities and programmes in the space field;
(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

The Agency is directed by a Council composed of representatives of Member States. The Director General is the chief executive of the Agency and its legal representative.

The Directorate of the Agency consists of the Director General; the Inspector General; the Director of Scientific Programmes; the Director of Observation of the Earth and its Environment; the Director of the Telecommunications Programme; the Director of Space Transportation Systems; the Director of the Space Station and Microgravity Programme; the Director of ESTEC; the Director of Operations and the Director of Administration.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

THE EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTRE (ESTEC), Noordwijk, Netherlands.

THE EUROPEAN SPACE OPERATIONS CENTRE (ESOC), Darmstadt, Germany

ESRIN, Frascati, Italy.

Chairman of the Council: Prof. F. Carassa

Director General: J.-M. Luton.

agence spatiale européenne

L'Agence Spatiale Européenne est issue des deux Organisations spatiales européennes qui l'ont précédée — l'Organisation européenne de recherches spatiales (CERS) et l'Organisation européenne pour la mise au point et la construction de lanceurs d'engins spatiaux (CECLES) — dont elle a repris les droits et obligations. Les Etats membres en sont: l'Allemagne, l'Autriche, la Belgique, le Danemark, l'Espagne, la France, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Royaume-Uni, la Suède et la Suisse. La Finlande est membre associé de l'Agence. Le Canada beneficie d'un statut d'Etat coopérant.

Selon les termes de la Convention: l'Agence a pour mission d'assurer et de développer, à des fins exclusivement pacifiques, la coopération entre Etats européens dans les domaines de la recherche et de la technologie spatiales et de leurs applications spatiales, en vue de leur utilisation à des fins scientifiques et pour des systèmes spatiaux opérationnels d'applications:

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications.
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

L'Agence est dirigée par un Conseil, composé de représentants des Etats membres. Le Directeur général est le fonctionnaire exécutif supérieur de l'Agence et la représente dans tous ses actes.

Le Directoire de l'Agence est composé du Directeur général; de l'Inspecteur général; du Directeur des Programmes scientifiques; du Directeur des Programmes d'Observation de la Terre et de son Environnement; du Directeur du Programme de Télécommunications; du Directeur des Systèmes de Transport spatial; du Directeur du Programme Station spatiale et Microgravité; du Directeur de l'ESTEC, du Directeur des Opérations et du Directeur de l'Administration.

Le SIEGE de l'Agence est à Paris.

Les principaux Etablissements de l'Agence sont:

LE CENTRE EUROPEEN DE RECHERCHE ET DE TECHNOLOGIE SPATIALES (ESTEC), Noordwijk, Pays-Bas.

LE CENTRE EUROPEEN D'OPERATIONS SPATIALES (ESOC), Darmstadt, Allemagne.

ESRIN, Frascati, Italie

Président du Conseil: Prof. F. Carassa

Directeur général: J.-M. Luton.

esa bulletin

no. 72 november 1992

contents/sommaire

Cover: Model of ERS-1 on display outside the Granada Congress Centre

Editorial/Circulation Office

ESA Publications Division
PO Box 299, Noordwijk
2200 AG The Netherlands

Publication Manager
Bruce Battrick

Editors
Bruce Battrick
Duc Guyenne
Clare Mattok

Layout
Carel Haakman

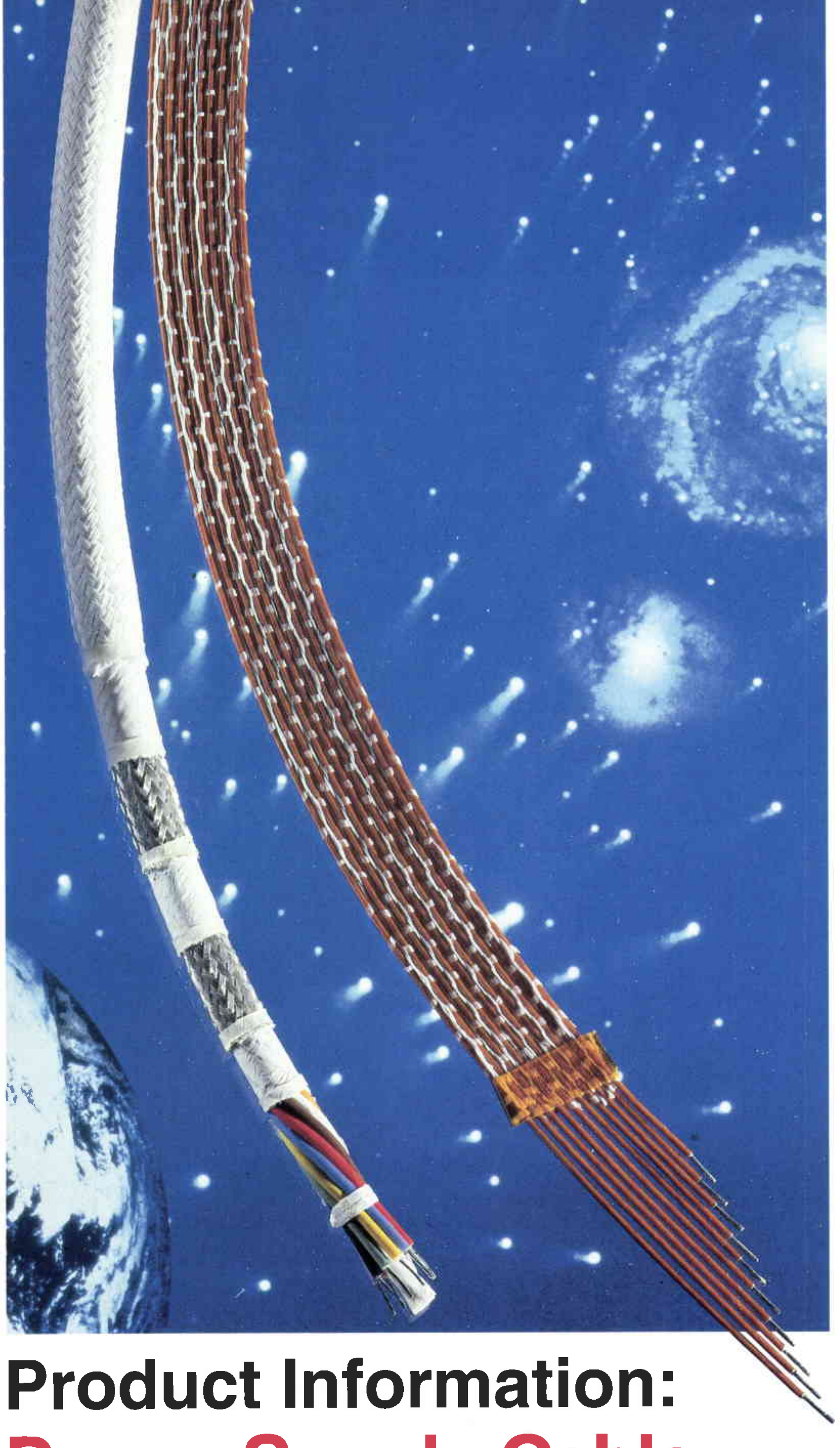
Graphics
Willem Versteeg

Montage
Keith Briddon
Paul Berkhout

Advertising
Brigitte Kaldeich

Printed in The Netherlands
ISSN 0376-4265

european space agency
agence spatiale européenne



GORE are specialists in cable constructions for critical transmission systems. GORE special high-performance cables secure the success of space missions through their application-specific design and manufacture.

Contact us early in your concept phase. We will be glad to advise you. We have extremly short turn-arounds for the design, prototyping and manufacture of your special cable requirements.

Main specializations

- Space wires and cables (qualification according to SPACELAB SLP 2110 and ESA/SCC detail specification 3901/007, 008, 009)
- Highly flexible, low-attenuation microwave cable assemblies, applicable up to 40 GHz
- Dielectric waveguides from 26.5 to 110 GHz
- Highly flexible, low-attenuation coaxial cables
- Round and flat conductor ribbon cables
- Data lines
- Round cables
- High voltage wires and cables

Product Information: Power Supply Cable Assemblies for Space Technology

GORE

W.L. GORE & ASSOCIATES GMBH
Nordring 1 · D-8835 Pleinfeld · Germany
Phone: (0 91 44) 6 01 - 0

Hermann-Oberth-Str. 22
D-8011 · Putzbrunn · Germany
Phone: (089)4612 - 507

High Technology and the Earth

More than 20 years ago the first pictures from space showed the earth in a completely new perspective. Since that time space has proved to be the most appropriate viewing point from which to investigate and reach a better understanding of our planet.

The European Space Agency ESA recognized early on the advantages of earth observation by satellite and, by the end of the seventies, began the planning stage of the ERS program. Due to their experience and success in space technology, responsibility for the development of the first European remote sensing satellite ERS-1 was assigned to Dornier.
Today ERS-1, equipped with the most modern instrumentation, produces, egardless of cloud cover and time of day, geophysical data on the oceans, polar ice-caps, coastal regions and selected areas of land. This completely new and valuable information is made accessible for use in environmental protection, climatic research, weather forecasting and oceanography.

As an important follow-up program the contract for the second remote sensing satellite ERS-2 has been awarded.

In continuation of this space technology program, the Polar Orbiting Earth Mission POEM-1 will, in the near future, offer an important contribution to atmospheric research. The large capacity of the POEM-1 payload will represent a new milestone in satellite development.

Dornier GmbH
Satellites and Application Systems
P.O. Box 14 20
D-7990 Friedrichshafen 1
Phone (07545) 8-36 85
Fax (0 75 45) 8-93 92

Dornier
Deutsche Aerospace

Spain at a glance

In 1992, Spain's international scope will be greatly enhanced, thanks to the Direct Broadcast Service antenna aboard the HISPASAT.

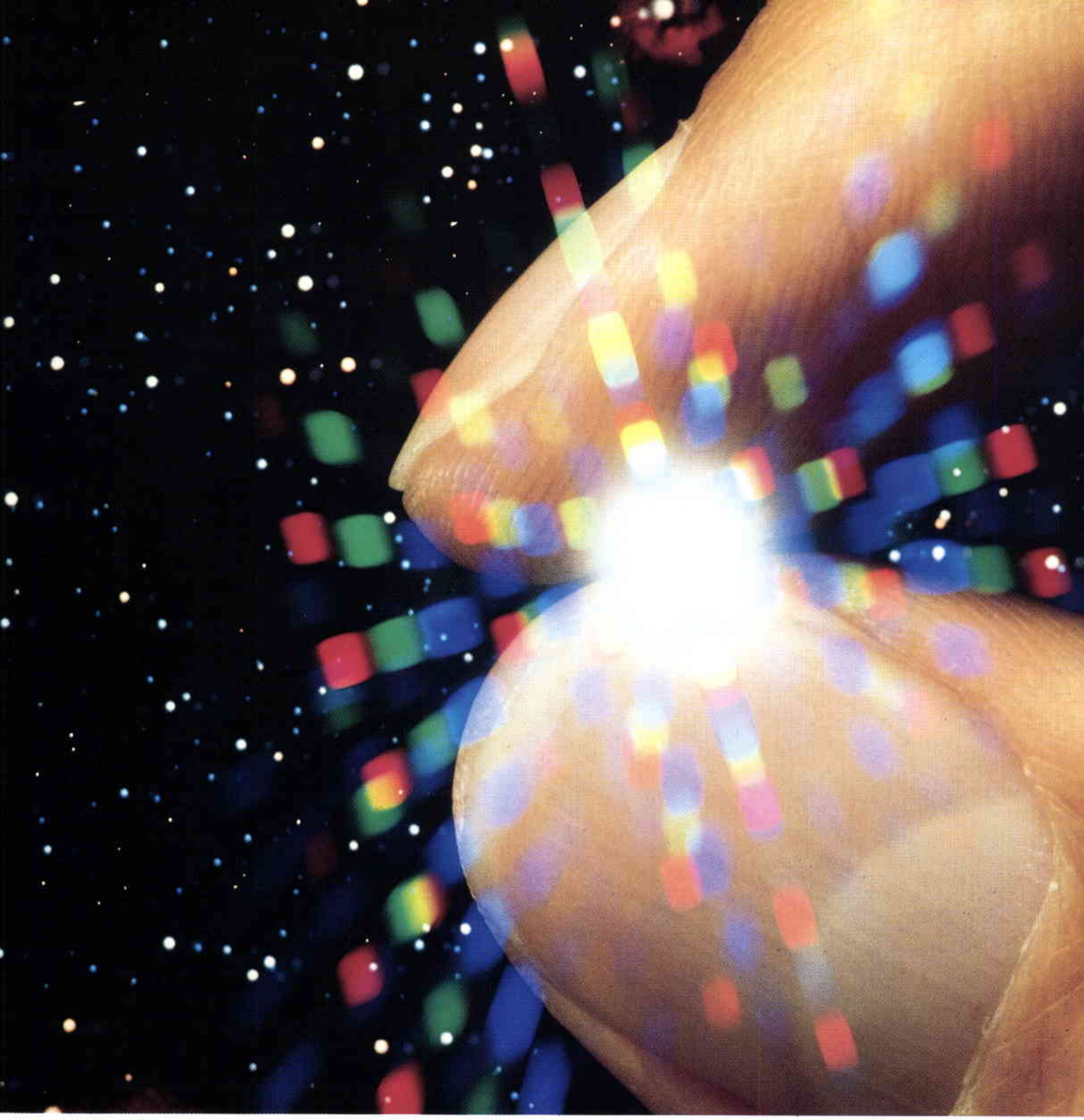
The DBS antenna was developed at CASA Space Division using the most advanced technology.

For the first time, Spain flies a telecommunications satellite that carries all the very best of CASA aboard.

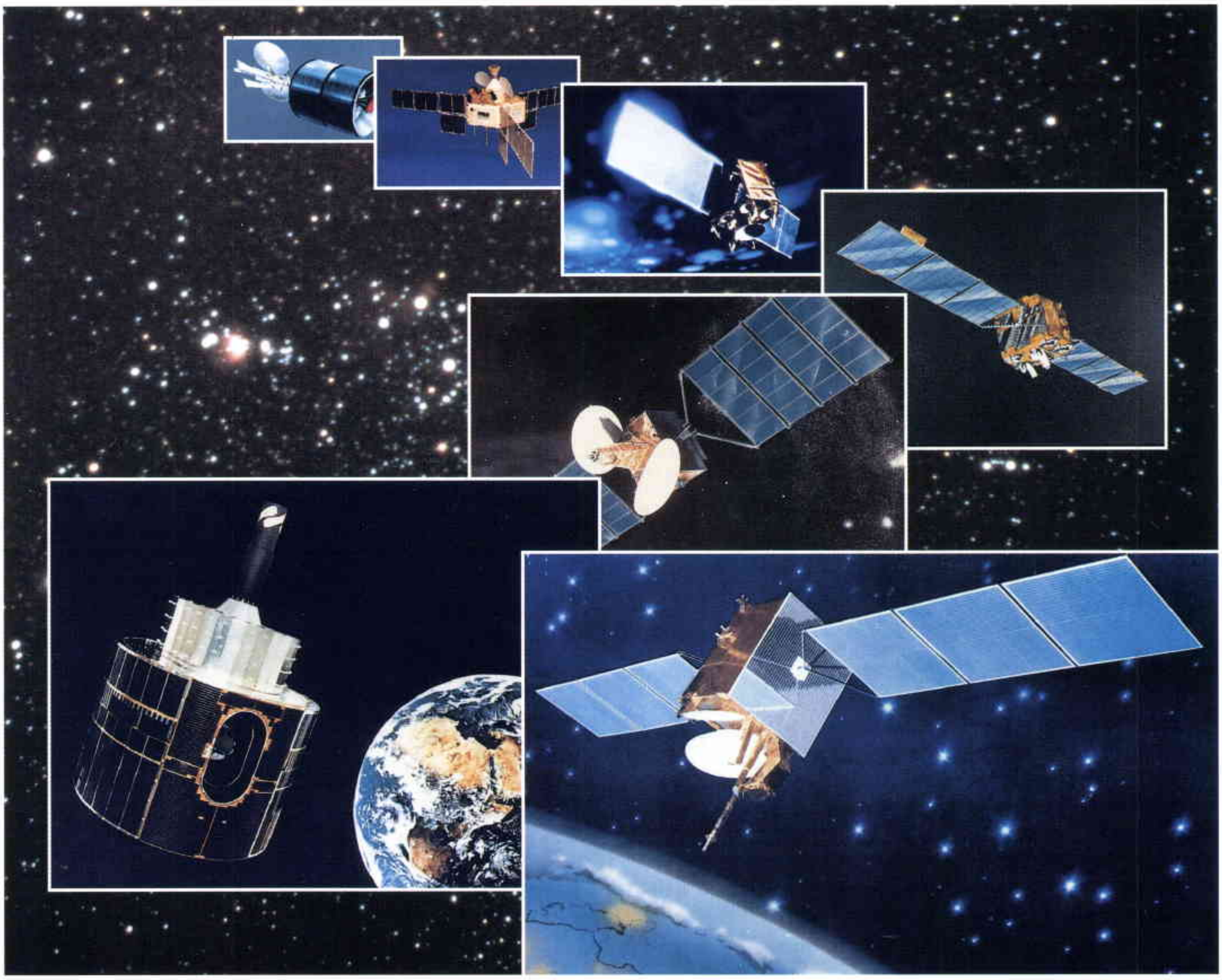
CASA has adopted a strong commitment for future missions, continuing to meet the challenges of the space age.

CASA
SPACE DIVISION

CONSTRUCCIONES AERONAUTICAS, S.A. Avda. de Aragón, 404 - 28022 MADRID. Tel.: 586 37 00 - Fax: 747 47 99 - Télex: 48540 CASA E.



ANT in Space - Experience and Knowledge in Satellite Communications



AN 9201 E.S.

ANT's space communications experience over 30 years with profound knowledge of the communication techniques together with its special theoretical background is highly appreciated by our customers.
Our flight hardware experience and capabilities are represented in more than 60 national and international satellites and orbital systems in which several million hours of lifetime in orbit have been accumulated without failure. That's our contribution to worldwide telecommunication such as telephone calls, data and TV signal transmission.

ANT Nachrichtentechnik GmbH
Space Communications Systems
Gerberstraße 33
7150 Backnang/Germany
Telephone +49/7191/13-21 84
Telefax +49/7191/13-25 34

Bosch Telecom

The Granada Ministerial Conference — The Issues and the Outcome

J.-M. Luton
Director General, ESA, Paris

Background

At their previous Meetings in Rome on 30 and 31 January 1985 and in The Hague on 9 and 10 November 1987, the Ministers responsible for space affairs in the ESA Member States decided upon, and subsequently confirmed, a Plan based on three main concepts: autonomy, coherence and balance:

- autonomy to be achieved through new and competitive launchers (Ariane-5)
- coherence to be ensured thanks to a combination of programmes (Columbus, Hermes, Data Relay System) that would provide Europe with independent access to low Earth orbits and ultimately lead to a complete, inhabited European in-orbit infrastructure, and
- a balance to be struck between science, applications and infrastructure programmes.

Mr Jean-Marie Luton (left) and Prof. Hubert Curien, who chaired the Granada Meeting

ESA was also to pursue its activities in Space Science, Earth Observation, Telecommunications and Microgravity.

By the time of the next Ministerial Meeting in Munich in November 1991, the situation had profoundly changed: there had been a slowdown in economic growth and a tightening of the resources available for research and development. This had been accompanied by major geo-political upheavals: the reunification of Germany, changes in the political system in the countries of Eastern Europe, and the acceleration of European integration. ESA had, of course, to take account of all of these factors.

The Member States took the decision in Munich to restructure the Long-Term Plan for the Agency, whilst at the same time reaffirming the guidelines established in The Hague. They adopted two Resolutions, one concerning a Plan for the years 1992–2005, and another dealing with Earth Observation. They also asked me to present, a year later, proposals reflecting the economic realities and the new political situations both in Europe and in the rest of the World.

The pre-Granada position

The proposals for the future of Europe's space programmes that I put forward for decision in Granada were built around the following concepts:

- continuation of the major scientific programmes
- preservation of European competitiveness in launch and telecommunications systems
- expansion of the programmes for observation of the Earth and its environment
- greater cooperation in crewed spaceflight.

To put these ideas into practice in a way that takes into account the changing World environment, a stepped approach was proposed, making it possible to introduce a measure of flexibility into programmes as they evolve while still maintaining the long-term aims.

The broad lines of the Plan proposed to the Ministers were therefore as follows:

- *Science Programme:* to maintain the levels of resources and aims already defined in the 'Space Science: Horizon 2000' Plan.

- *Observation of the Earth and its Environment:* to give priority to the programmes concerned. Following ERS-1, already in orbit, and ERS-2, to be launched in 1994, it was proposed that two series of polar-orbiting missions should be developed: the first devoted to the environment, with a possible 1998 launch and carrying a more advanced and more powerful synthetic-aperture radar than ERS; the second focussing on meteorology, to be launched in 2000 and carrying instruments designed for climatic studies.

- *Telecommunications:* to launch, between now and the year 2000, two telecommunications satellites, and to fly two payloads on non-ESA satellites. The two satellites, Artemis (Advanced Relay and Technology Mission Satellite) and DRS-1 (Data Relay Satellite) would be launched in 1996 and 1999, respectively, to provide the first Earth-observation platform in polar orbit with a data-relay capability. The two payloads in question were the European Land-Mobile System (EMS), scheduled for launch in 1994 on Italsat-F2, and an On-Board Processing (OBP) system, to be launched in 1996 on an as yet unspecified satellite.

- *Launchers:* to continue development of Ariane-5, which began in 1988, to ensure a launch capability for initially automatic and later crewed space vehicles.

- *Space Transportation:* the Hermes Programme, having evolved considerably since the preparatory phase began in 1985, and prompted by technical, financial and political considerations, to undertake a three-year re-orientation phase centering primarily on: defining an ESA-Russian programme to include a crew transport system and servicing elements for low Earth orbits; and studying an Assured Crew Return Vehicle (ACRV) in conjunction with NASA, and an Automated Transfer Vehicle (ATV) within the framework of utilisation of the Columbus Attached Laboratory.

  A decision on whether to proceed with the development phases of these programmes would be taken in 1995.

- *In-Orbit Infrastructure:* to develop the Columbus Attached Laboratory to be launched in 1999 as part of the International Space Station 'Freedom'; to undertake definition studies for a future ESA-Russian Space Station, including a contribution to the Mir-2 programme, on which a decision to proceed to the development phase should also be taken in 1995; and to undertake precursor flights.

ESA exhibits in the foyer of the Granada Congress Centre

These then were the main themes of the realistic, but still ambitious plan, that was submitted to the Ministers in Granada for approval. It took account of the Member States' resolve to preserve a European industrial capability and to expand the range of cooperative activity.

Decisions in Granada

As the accompanying Resolutions show, in Granada we witnessed a positive outcome from a year of intensive endeavour within the Agency. Many of the difficulties that the

The 1992 Ministerial Council Meeting in progress

Member States faced in Munich have been resolved, allowing a broad consensus to be reached.

The deliberations of the Ministers were characterised not only by an appreciation of the problems that several of our Member States are currently facing, but also by a marked willingness to find a compromise.

As expected, far-reaching and important decisions were taken in the field of Earth observation, where the green light was given to develop Envisat-1 and to pursue cooperation with Eumetsat on future geostationary and polar-orbiting missions.

Regarding the programmes associated with man in space, the Ministers agreed that the global development of the Columbus Attached Laboratory (APM) can now start, as can the development of the Columbus Polar Platform and the Data Relay Satellite. With the 5% cut in project costs that has been accepted for the APM, I am confident that we will see this programme fully subscribed in the coming months.

It was also agreed that the Ministers will decide in February 1995 on the utilisation phase for the Columbus APM, and I will be leading fresh negotiations with NASA to find ways of accommodating the wishes of the Member States that the exploitation costs of the International Space Station should, in significant measure, be delivered in kind. This would include European provision or involvement in such services as the Automated Transfer Vehicle, the Assured Crew Return Vehicle, and the Data Relay System.

The Ministers took the decision to continue with the re-orientation of the Hermes Programme towards greater and deeper cooperation with Russia, to arrive at a crewed space transportation system developed from Hermes. They will be reviewing the progress of the programme in 1995.

The Ministers reaffirmed their support for the Agency's Science Programme and for the full and timely realisation of the 'Space Science: Horizon 2000' Programme as a key element of European Space Policy. In addition, I was invited to draw up a plan, in consultation with the scientific community, for a European Space Science Policy beyond 'Horizon 2000'.

The Ministers underlined the positive results achieved in the Ariane development and operational programmes and stressed its strategic importance for the European space endeavour, which must be preserved. In this respect, they appealed for European solidarity to further support the use of the Ariane launchers.

Those Member States that have suffered from recent monetary fluctuations were particularly worried about its effects on the mechanisms used for calculating their contributions to ESA. I have undertaken to devise an equitable interim solution for these countries before the Agency's Council meets in December. Thereafter, the whole question of contributions will be examined in detail with a view to avoiding such difficulties in the future.

The Ministers stressed the need for synergy between ESA's activities and those of the European Community, Eutelsat and Eumetsat in the fields of Earth observation, telecommunications, and research and technology. They welcomed what had been achieved with the Agency's international partners, particularly the United States, Russia and Japan, and look for intensification and expansion of those relations.

Relations with Russia received particular attention, with emphasis on joint studies in the areas of in-orbit infrastructure and associated communications, manned transportation systems and missions by European astronauts to the Mir Station. Cooperation with other former countries of the USSR might also be considered.

All in all, we now have a period in which we can proceed with confidence with our planned activities, both within the Agency and in European industry. The Granada Conference has given ESA the mandate to move ahead with the European Long-Term Space Plan. The Ministers will next meet to review progress in February 1995.

First row, left to right: Mr Jean-Maurice Dehousse, Ministre de la Politique Scientifique, Belgium; Prof. Hubert Curien, Ministre de la Recherche et de l'Espace, France; Prof. Kerstin Fredga, Chairman & Director General, Swedish National Space Board; Prof. Francesco Carassa, Chairman of ESA Council; Mr Claudio Aranzadi, Minister of Industry, Trade and Tourism, Spain; Mrs Anne Breiby, State Secretary–Ministry of Industry, Norway; Mr Jean-Marie Luton, ESA Director General; Prof. Sandro Fontana, Ministro dell'Università e della Ricerca Scientifica e Tecnologica, Italy; Mr Jesus Quero Molina, Excelentisimo Alcalde de Granada.

Second row: Mr Henrik Grage, Head of Delegation, Denmark; Dr. Raoul Kneucker, Sektionschef–Bundesministerium für Wissenschaft und Forschung, Austria; Dr. Michael F. Fahy, Department of Industry and Commerce, Ireland; Dr. Jacobus Andriessen, Minister of Economic Affairs, The Netherlands; Dr. Heinz Riesenhuber, Bundesminister für Forschung und Technologie, Germany; Mr Edward Leigh, Minister for Trade and Industry, United Kingdom; Mr Pekka Tuomisto, Minister of Trade and Industry, Finland; Mr l'Ambassadeur Francois Nordmann, Directeur, Chef de la Direction des Organisations internationales du Département fédéral des affaires étrangères, Switzerland; Dr. Roland Doré, President of the Canadian Space Agency

Opening Address

C. Aranzadi
Minister of Industry, Trade and Tourism, Spain

I have great pleasure in greeting all the Delegations taking part in this Ministerial Meeting of the European Space Agency's Council and at the same time in expressing our sincere gratitude to the city of Granada for its cordial welcome.

We are meeting in 1992, a symbolic year for so many reasons, including the fact that it is International Space Year. This has been a year of great intensity and of crucial importance in conveying to society at large the role that space exploration is called upon to play in the closing stages of the 20th century.

Mr Claudio Aranzadi (centre) delivering his Opening Address, with Mr Jesus Quero Molina, Mayor of Granada, and Prof. Francesco Carassa (right), Chairman of the ESA Council

We are preparing to draw together the intensive work carried out over the last year, especially within the Agency itself, firmly convinced of the need to harmonise our efforts and adapt Europe's space plans to the new political and economic environment.

There is no doubt that we are faced with new realities, with changing circumstances, which have introduced fresh complexity into the long-term outlook for Europe's space plans. We must not, however, lose sight of a series of considerations which, despite these changes, remain valid for all concerned.

Firstly, space cooperation is directed at the most ambitious and at the same time noblest project pursued by humanity – the exploration and conquest of outer space. Space is something that stimulates our imagination and gives us a sense of being citizens of the World. It behooves Europe to make a major contribution to this great planetary challenge if it wishes to live up to the World's expectations of it.

Secondly, we have to remember that a better understanding of space brings with it important scientific and technological advances, which help to improve the quality of life for our citizens. In today's environment, the concept of 'useful space' is becoming increasingly relevant, in so far as space offers great potential for providing the community with services in the areas of telecommunications, weather forecasting and the utilisation of natural resources, to give but three examples. The benefits of space activities are having an ever-growing impact on our daily lives. We rely on communications satellites; we observe our planet from geostationary and polar orbits to make weather forecasts and study environmental matters; we use satellites and interplanetary probes to improve our knowledge of the Universe and its origins; we are also conducting very important research in the life- and materials-sciences in environments with close to zero gravity.

Nor should we lose sight of the strongly industrial facet of space exploration. Account must of course be taken of the employment and income generated directly by the aerospace industry, but it is also fundamentally important to consider that advanced space technologies are rejuvenating and modernising our whole economy as the technologies concerned (informatics, telecommunications, new materials, etc.) spread to other sectors of production.

It is thus clear that the space programmes not only allow us to satisfy our natural curiosity concerning the Univers, but also carry a multiplier effect of enormous value.

By their very nature, space programmes bring a global approach to research and, in this way, make a decisive contribution to the development of solutions to problems of global and regional significance. This feature of space programmes is particularly clear in all areas relating to climatic change and the Earth's environment. Problems such as desertification, the destruction of the ozone layer, and deforestation, to name but a few, are being usefully studied from space.

But space projects also involve another element that is of the highest value for our peoples, namely the need for cooperation transcending the limits of local frontiers. In the space domain, cooperation is not solely a financial necessity, in view of the considerable resources needed to carry through the projects concerned; space cooperation also calls upon the available sum of human resources and enthusiasm, two major assets which Europe is perhaps alone in possessing in such quantity. I am tempted to go further: Europe needs such major collective challenges as space in order to enhance its unity and strengthen its position in the World. Major challenges are also a key factor in cohesion.

In pursuing this great challenge for the future of exploring and investigating space, we must not forget our neighbours to the East, with whom both our hearts and our minds bid us to cooperate more closely. Our hearts call for the integration of countries destined to form part of greater Europe, while our minds demand a rational economic approach, with the efficient allocation of limited resources.

At the same time, space exploration being a common challenge for humanity, we must seek to cooperate constructively with the other space powers, and in particular the United States and Japan, making best use of any possible synergies between the various programmes and capabilities.

For these various reasons, the overall objectives established in Rome and in The Hague, and subsequently endorsed in Munich, remain entirely valid. It is essential not to lose sight of those goals, above all at a time when European space cooperation within the framework of ESA is already producing results: our leading position in launch services; the prestige of the Science Programme, which this year has given us great cause for satisfaction with the Giotto mission and the discoveries by the Ulysses probe concerning the structure of Jupiter's magnetosphere. Of importance too is the success of the mission being performed by ERS-1, which is proving to be a powerful tool for investigating the Earth and which will be followed by its companion, ERS-2.

The Granada Congress Centre

However, we cannot and must not rejoice too soon. We are all faced with considerable doubts where specific programme plans are concerned, and it is these doubts which we must strive to dispel during these two days in Granada. It is necessary for the sake of our industries, for the sake of our institutions and their credibility and, finally, for Europe's space future, to eliminate areas of uncertainty and establish a clear and realistic framework within which to act in the years ahead.

I believe in this regard – and I note that we have all come here with the same resolve – that we must do all we can to define the objectives of our future action, and the resources required to achieve them, and this implies a generous attitude that rises above minor and partial aims for the sake of the common good.

We must therefore be ready to meet these challenges responsibly and with determination, enthusiastically and generously, but also realistically and in a spirit of pragmatism. Let our debates be passionate and heated and yet constructive. Let us approach this Conference rationally, but also with generosity, and may we not forget that Europe's future in space lies in our hands.

Resolution on the Implementation of the European Long-Term Space Plan and Programmes

adopted on 10 November 1992

The Council meeting at Ministerial Level,

HAVING REGARD to ESA/C-M/XCVII/Res. 1 (Final) on the European Long-Term Space Plan 1992–2005 and programmes, adopted in Munich on 20 November 1991,

HAVING REGARD to ESA/C-M/XCVII/Res. 2 (Final) on programmes for observation of the Earth and its environment, adopted in Munich on 20 November 1991,

HAVING REGARD to the Director General's proposal for the Agency's policy and programmes (ESA/C-M(92)3), submitted in response to the instruction given by Council meeting at Ministerial Level in Munich on 19 and 20 November 1991 to achieve the best possible relationship between the requirements of cost and effectiveness, in particular through a widened and strengthened cooperation with States that have already developed advanced space technologies,

NOTING the work already done in the Agency's delegate bodies to prepare or adapt the legal instruments relating to the programmes on which decisions were called for in the above-mentioned Resolutions of Council meeting at Ministerial Level,

CHAPTER I
Long-Term Space Plan

1. ENDORSES the Director General's proposal for the Agency's policy and programmes referred to in the preamble, as a revision of the European Long-Term Space Plan 1992–2005 which constitutes the strategic framework for the Agency's activities, planning and programmes.

2. ENDORSES the introduction in the planning of the Agency's major optional programmes of a stepped approach aimed at reconciling the need to maintain continuity in the Agency's programmes and activities with the ability to respond, when needed, to the changes taking place in the overall political, financial, scientific and technological environment. This approach allows the taking of immediate decisions on developing certain programme elements and on reorientation activities over the period 1993–95, with a view to preparing for necessary complementary decisions in 1995.

3. RECOGNISES that the Director General's proposal ensures the continuity of European space policy while allowing for a gradual widening of international cooperation to the benefit of the Agency's programmes.

CHAPTER II
Decisions on Programmes called for in Resolution of Council Meeting at Ministerial Level of 20 November 1991

ENDORSES the decisions taken by the States participating in the various programmes referred to in this Chapter, which are made in accordance with the Director General's proposal for the Agency's policy and programmes (ESA/C-M(92)3) and permit the continuation and satisfactory execution of those programmes in accordance with the Resolutions of Council meeting at Ministerial Level of 20 November 1991 referred to in the preamble.

WELCOMES the decisions taken at this Ministerial Meeting by the States participating in the programmes referred to in this chapter, which constitute the agreed basis for amending the Declaration applicable to each of the said programmes.

Résolution sur la mise en oeuvre du plan spatial européen à long terme et des programmes

adoptée le 10 novembre 1992

Le Conseil siégeant au niveau ministériel,

VU la Résolution ESA/C-M/XCVII/Rés. 1 (Final) sur le Plan spatial européen à long terme 1992–2005 et les programmes, adoptée à Munich le 20 novembre 1991,

VU la Résolution ESA/C-M/XCVII/Rés. 2 (Final) sur les programmes d'observation de la Terre et de son environnement, adoptée à Munich le 20 novembre 1991,

VU la proposition du Directeur général relative à la politique et aux programmes de l'Agence (ESA/C-M(92)3), soumise en réponse aux instructions données par le Conseil siégeant au niveau ministériel à Munich les 19 et 20 novembre 1991 en vue d'atteindre le meilleur rapport possible entre les impératifs de coût et d'efficacité, en particulier grâce à un élargissement et à un renforcement de la coopération avec des Etats ayant déjà développé des technologies spatiales avancées,

PRENANT NOTE des travaux déjà accomplis au sein des organes délibérants de l'Agence en vue de préparer ou d'adapter les instruments juridiques relatifs aux programmes au sujet desquels des décisions ont été demandées dans les Résolutions du Conseil siégeant au niveau ministériel précitées.

CHAPITRE I
Plan spatial à long terme

1. ENTERINE la proposition du Directeur général relative à la politique et aux programmes de l'Agence visée au preambule à titre de révision du Plan spatial européen à long terme 1992–2005 qui constitue le cadre stratégique des activités, plans et programmes de l'Agence.

2. ENTERINE l'introduction dans la planification des grands programmes facultatifs de l'Agence d'une méthode par étapes visant à concilier la nécessité de maintenir la continuité des programmes et activités de l'Agence et la capacité de réagir, en cas de besoin, aux modifications intervenant dans le contexte politique, financier, scientifique et technologique. Cette méthode permet de prendre des décisions immédiates en ce qui concerne la réalisation de certains éléments de programme et la conduite d'activités de réorientation sur la période 1993–1995, en vue de préparer les décisions complémentaires qui devront être prises en 1995.

3. RECONNAIT que la proposition du Directeur général assure la continuité de la politique spatiale européenne tout en donnant les moyens d'élargir graduellement la coopération internationale au bénéfice des programmes de l'Agence.

CHAPITRE II
Décisions relatives aux programmes appelées par les Résolutions du Conseil siégeant au niveau ministériel le 20 novembre 1991

ENTERINE les décisions prises par les Etats participant aux différents programmes visées dans le présent chapitre, lesquelles sont conformes à la proposition du Directeur général relative à la politique et aux programmes de l'Agence (ESA/C-M(92)3) et permettent de poursuivre et d'exécuter lesdits programmes de façon satisfaisante en accord avec les Résolutions adoptées par le Conseil siégeant au niveau ministériel le 20 novembre 1991 visées au préambule.

ACCUEILLE FAVORABLEMENT les décisions prises au cours de la présente session ministérielle par les Etats participant aux programmes visés dans le présent chapitre, décisions qui constituent la base approuvée pour amender la Déclaration applicable à chacun desdits programmes.

A. Programmes for Observation of the Earth and Its Environment

1. NOTES the decision of the States participating in the POEM-1 programme that the work undertaken in 1992 pursuant to the decision taken on 20 November 1991 by Council meeting at Ministerial Level entails completion of Phase 1 of the POEM-1 programme on 31 December 1992;

2. NOTES that the POEM-1 programme will comprise as of 1 January 1993 the two elements described below and that, in accordance with the Director General's proposal referred to in the preamble which fulfils the requirement for a report contained in Chapter III of Resolution ESA/C-M/XCVII/Res.2 (Final), both elements will use the Polar Platform developed under the Columbus programme and use the Data Relay System (DRS) for data transmission, telemetry and command:

   (1) the Envisat-1 mission planned for launch in 1998, which will be mainly dedicated to inderstanding and monitoring the environment and to providing radar data as a continuation of the data provided by ERS-2 through inclusion of the instruments referred to in the Director General's proposal;

   (2) the Metop-1 mission planned for launch in 2000, which will provide operational meteorological observations, to be carried out taking into account the requirements expressed by the Eumetsat Council and in accordance with the terms of an Agreement to be concluded with Eumetsat.

3. NOTES the decision of the States participating in the POEM-1 programme to execute the Envisat-1 mission with an allocated financial envelope estimated at 1134.5 MAU at mid-1991 economic conditions and the preparatory activities for the Metop-1 mission with an allocated financial envelope estimated at 40 MAU at the same economic conditions, it being understood that the corresponding envelopes will be financed in accordance with the contribution scales in Table I attached hereto, giving a total of 1174.5 MAU.

4. INVITES the States participating in the POEM-1 programme to decide before the end of 1994 to develop the Metop-1 mission on the basis of a proposal from the Director General, accompanied by a cooperation Agreement negotiated with Eumetsat; and NOTES that, on current assumptions, the Agency's contribution to Metop-1 development is estimated at 625 MAU at mid-1991 economic conditions, which includes the costs of the DRS terminal.

5. WELCOMES the Resolution adopted by the Eumetsat Council at its meeting of 22–23 September 1992 confirming Eumetsat's intention to cooperate with ESA in developing a second generation of Meteosat satellites and to contribute to the Metop-1 mission. The preparatory activities for the Metop-1 mission take due account of the above resolution. The relevant parallel decisions by the Eumetsat Council on financing Eumetsat's own preparatory activities will be needed by mid-1993. Such decisions by the Eumetsat Council are required in order for the Agency to decide whether the Metop-1 mission will be continued unchanged beyond 1993 or will be modified.

6. NOTES that, in accordance with the Director General's proposal referred to in the preamble, and in particular Annex 8 thereto, the Envisat-1 ground segment will have recourse to both the Agency's and national facilities developed for ERS-1 and ERS-2, will take account of the ongoing Phase B studies and will be further designed to provide efficient linkage with the systems being developed worldwide, and in particular in the environmental science community.

7. RECOGNISES that the Agency's activities and programmes in the field of observation of the Earth and its environment play an important role in providing suitable means for monitoring ice, oceans and the atmosphere; and RECOGNISES further that these activities and programmes contribute to a coherent and effective European Earth-observation policy, which, among other things, takes into account the uses that developing countries can make of observation data.

8. INVITES the Director General to take the initiative of consulting with European entities active in the field, in particular the Commission of the European Communities, Eumetsat, appropriate national bodies and the user communities, with a view to acquiring a solid basis for the formulation and strengthening of a European Earth-observation policy as an element of a worldwide strategy.

A. Les programmes d'observation de la Terre et de son environnement

1. PREND NOTE de la décision des Etats participant au programme POEM-1 selon laquelle les travaux entrepris en 1992 en application de la décision prise le 20 novembre 1991 par le Conseil siégeant au niveau ministériel conduisent à l'achèvement de la phase-1 du programme POEM-1 le 31 décembre 1992;

2. NOTE que le programme POEM-1 comprendra, à partir du 1er janvier 1993, les deux éléments décrits ci-dessous et que, conformément à la proposition du Directeur général visée au préambule qui fait droit à l'obligation de faire rapport inscrite au chapitre III de la Résolution ESA/C-M/XCVII/Rés. 2 (Final), ces deux éléments utiliseront la plate-forme polaire réalisée dans le cadre du programme Columbus et le système de relais de données (DRS) pour la transmission des données, la télémesure et la télécommande:
   (1) la mission Envisat-1, dont le lancement est fixé à 1998, qui aura pour principal objet la connaissance et la surveillance de l'environnement, ainsi que la fourniture de données radar en continuité des données d'ERS-2 par l'emport des instruments visés dans la proposition du Directeur général;
   (2) la mission Métop-1, dont le lancement est fixé à l'an 2000, chargée d'observations météorologiques opérationnelles, qui sera conduite compte tenu des besoins formulés par le Conseil d'Eumetsat et conformément aux termes d'un Accord à conclure avec Eumetsat.

3. PREND NOTE de la décision des Etats participant au programme POEM-1 d'exécuter la mission Envisat-1 dans les limites d'une enveloppe financière estimée à 1134,5 MUC aux conditions économiques de la mi-1991 et les activités préparatoires de la mission Métop-1 dans les limites d'une enveloppe financière estimée à 40 MUC aux mêmes conditions économiques, ce qui aboutit à un total de 1174,5 MUC, étant entendu que les enveloppes correspondantes seront financées conformément aux barèmes des contributions figurant au tableau I ci-joint.

4. INVITE les Etats participant au programme POEM-1 à décider avant la fin de 1994 de réaliser la mission Métop-1 sur la base d'une proposition du Directeur général accompagnée d'un Accord de coopération négocié avec Eumetsat; et NOTE que, selon les hypothèses actuelles, la contribution de l'Agence à la réalisation de Métop-1 est estimée à 625 MUC aux conditions économiques de la mi-1991, coûts du terminal DRS compris.

5. ACCUEILLE FAVORABLEMENT la Résolution adoptée par le Conseil d'Eumetsat lors de sa réunion des 22 et 23 septembre 1992 qui confirme qu'Eumetsat a l'intention de coopérer avec l'ESA à la réalisation d'une deuxième génération de satellites Météosat et de contribuer à la mission Métop-1. Les activités préparatoires de la mission Métop-1 tiennent dûment compte de la Résolution précitée. Il conviendrait que le Conseil d'Eumetsat prenne d'ici la mi-1993 les décisions parallèles pertinentes ayant trait au financement des activités préparatoires propres à Eumetsat. Ces décisions doivent être prises par le Conseil d'Eumetsat pour que l'Agence puisse décider si la mission Métop-1 se poursuivra telle quelle au-delà de 1993 ou si elle sera modifiée.

6. NOTE que, conformément à la proposition du Directeur général visée au préambule, et en particulier à son annexe 8, le secteur sol d'Envisat-1 fera appel aux installations de l'Agence et aux installations nationales réalisées pour ERS-1 et ERS-2, prendra en compte les études de phase-B en cours et sera en outre conçu de manière à assurer une liaison efficace avec les systèmes en cours de réalisation au niveau mondial, et en particulier dans le cadre de la communauté des spécialistes des sciences de l'environnement.

7. RECONNAIT que les activités et programmes de l'Agence dans le domaine de l'observation de la Terre et de son environnement jouent un rôle important en matière de protection de l'environnement, notamment en fournissant des moyens adaptés à la surveillance des glaces, des océans et de l'atmosphère; et RECONNAIT en outre que ces activités et programmes contribuent à la cohérence et à l'efficacité de la politique européenne d'observation de la Terre, qui tient compte, entre autres choses, de l'utilisation que les pays en développement peuvent faire des données d'observation de la Terre.

8. INVITE le Directeur général à prendre l'initiative de consulter les entités européennes actives dans ce domaine, notamment la Commission des Communautés européennes, Eumetsat, les entités nationales

B. The DRS Element of the DRTM Programme

1. NOTES the decision taken by the States participating in the DRS element of the DRTM programme that the work undertaken so far, pursuant to the decision taken on 20 November 1991 by Council meeting at Ministerial Level and including tasks within the Data-Relay Preparatory Programme, the Technology Mission and Phase 1 of the DRS Programme Element, entails the completion of definition activities and constitutes a satisfactory basis for initiating the development of the Data-Relay System.

2. NOTES that the DRS Programme Element will comprise as of 1 January 1993 the full development of the first DRS satellite for launch in 1999 in order to meet the requirements of the Earth observation and other programmes; and INVITES the participating States to take a complementary decision in February 1995 with regard to the integration and launch of the second flight unit.

3. NOTES the decision of the States participating in the DRS element of the DRTM programme to execute the full development of the DRS system with an overall corresponding financial envelope estimated at 945 MAU at mid-1991 economic conditions (of which 199.4 MAU are the subject of the complementary decision mentioned in paragraph (2), it being understood that the corresponding envelope will be financed in accordance with the contribution scale in Table I attached hereto.

C. The Columbus Programme

1. NOTES the decision taken by the States participating the Columbus Programme that the work undertaken in 1992 pursuant to the decision taken on 20 November 1991 by Council meeting at Ministerial Level entails completion of Phase 1 of the Columbus Programme on 31 December 1992.

2. NOTES that the Columbus Programme will comprise as of 1 January 1993 the four elements described below:

   (1) development and launch of the Columbus Attached Laboratory, including the development of the ground segment and the conduct of operational and utilisation activities up to the launch planned for 1999;
   (2) development and launch, which is planned for 1998, and initial operations of the Columbus Polar Platform, including the ground segment necessary for its control;
   (3) execution of the Columbus precursor-flight activities to prepare for exploitation of the Columbus Attached Laboratory and to provide intermediate flight opportunities for th user community;
   (4) execution over the period 1993–95 of system studies and definition activities involving international cooperation on a future crewed in-orbit infrastructure, in order to prepare for activities to be carried out in the second planning step.

3. NOTES the decision of the States participating in the Columbus Programme to execute development of the Columbus Attached Laboratory with an allocated financial envelope estimated at 2516.8 MAU at mid-1991 economic conditions, of which 350.0 MAU are allocated to the preparation for utilisation and operation are subject to a complementary decision to be taken by a double two-thirds-majority vote of the participating States in February 1995 as indicated in Chapter III, and development of the Polar Platform with an allocated financial envelope estimated at 694.0 MAU at the same economic conditions, to proceed with execution of Columbus precursor flights, including MIR flights, with an allocated financial envelope estimated a 315.9 MAU at the same economic conditions, and the execution of studies on a future crewed in-orbit infrastructure, with an allocated financial envelope estimated at 30.0 MAU at the same economic conditions; it is further understood in that decision that the corresponding envelopes, amounting to 3556.7 MAU, will be financed with regard to activities undertaken as of 1 January 1993 in accordance with the contribution scales in Table I attached hereto.

4. INVITES the Director General to take the appropriate measures, possibly including prolongation of the development of the Columbus Attached Laboratory by a maximum of one year, so as to reconcile the requirements of the programme with the financial resources made available by the participating States, as indicated in Table I attached hereto.

compétentes et les communautés d'utilisateurs, afin d'asseoir sur des bases solides l'élaboration et le renforcement d'une politique européenne d'observation de la Terre en tant qu'élément d'une stratégie mondiale.

B. L'élment DRS du programme DRTM

1. PREND NOTE de la décision des Etats participant à l'élément DRS du programme DRTM selon laquelle les travaux exécutés à ce jour, en application de la décision prise le 20 novembre 1991 par le Conseil siégeant au niveau ministériel et comprenant les tâches faisant partie du programme préparatoire de relais de données, de la mission de technologie et de la phase-1 de l'élément de programme DRS, conduisent à l'achèvement des activités de définition et constituent une base satisfaisante pour mettre en route le développement du système de relais de données.

2. NOTE que l'élément de programme DRS comprendra, à partir du 1er janvier 1993, la réalisation effective du premier satellite DRS pour qu'il puisse être lancé en 1999 en vue de satisfaire les impératifs des programmes d'observation de la Terre et d'autres programmes et INVITE les Etats participants à prendre, en février 1995, une décision complémentaire au sujet de l'intégration et du lancement de la deuxième unité de vol.

3. PREND NOTE de la décision des Etats participant à l'élément DRS du programme DRTM de mener à bien la réalisation du système de relais de données dans les limites d'une enveloppe financière globale estimée à 945 MUC aux conditions économiques de la mi-1991 (dont 199,4 MUC doivent faire l'objet de la décision complémentaire mentionnée au paragraphe 2, étant entendu que l'enveloppe correspondante sera financée conformément au barème des contributions qui figure au tableau I ci-joint.

C. Le programme Columbus

1. PREND NOTE de la décision des Etats participant au programme Columbus selon laquelle les travaux entrepris en 1992 en application de la décision prise le 20 novembre 1991 par le Conseil siégeant au niveau ministériel conduisent à l'achèvement de la phase 1 du programme Columbus le 31 décembre 1992.

2. NOTE que le programme Columbus comprendra, à partir du 1er janvier 1993, les quatre éléments décrits ci-dessous:
   (1) la réalisation et le lancement du laboratoire raccordé Columbus, y compris la réalisation du secteur sol et la conduite des activités opérationnelles et d'utilisation jusqu'au lancement prévu en 1999;
   (2) la réalisation et le lancement, prévu en 1998, ainsi que l'exploitation initiale de la plate-forme polaire Columbus, y compris le secteur sol nécessaire à la commande et au contrôle de celle-ci;
   (3) l'exécution des vols précurseurs Columbus pour préparer l'exploitation du laboratoire raccordé Columbus et fournir à la communauté des utilisateurs des occasions de vol intermédiaires;
   (4) l'exécution, au cours de la période 1993–1995, d'activités de définition et d'études système, mettant en jeu une coopération internationale sur une future infrastructure orbitale habitée, en vue de préparer les activités à exécuter dans la deuxième étape du calendrier.

3. PREND NOTE de la décision des Etats participant au programme Columbus de procéder à la réalisation du laboratoire raccordé Columbus dans les limites d'une enveloppe financière estimée à 2516,8 MUC aux conditions économique de la mi-1991, dont 350 MUC affectés à la préparation de l'utilisation et de l'exploitation feront l'objet d'une décision complémentaire que les Etats participants doivent prendre à la double majorité des deux tiers en février 1995 comme il est dit au chapitre III et à la réalisation de la plate-forme polaire dans les limites d'une enveloppe financière estimée à 694,0 MUC aux mêmes conditions économiques, à l'exécution des vols précurseurs Columbus, vols Mir compris, dans les limites d'une enveloppe financière estimée à 315,9 MUC aux mêmes conditions économiques, et à l'exécution d'études sur une future infrastructure orbitale habitée dans les limites d'une enveloppe financière estimée à 30 MUC aux mêmes conditions économiques, ce qui aboutit à un total de 3556,7 MUC; étant entendu, aux termes de cette décision, que les enveloppes correspondantes seront financées, en ce qui concerne les activités entreprises à partir du 1er janvier 1993, conformément aux barèmes des contributions qui figurent au tableau I ci-joint.

5. TAKES due account of the preliminary information, provided in the Director General's proposal referred to in the preamble, on the envisaged costs and principles for sharing the costs of the exploitation programme for the Columbus Attached Laboratory and INVITES the Director General to formulate a final proposal in this regard so that a decision on the said exploitation programme can be taken in due time.

6. INVITES the States participating in the Columbus Programme to monitor closely the evolution of development of the International Space Station and to take decisions as appropriate to provide for the necessary adjustment of the programme.

7. RECOGNISES the Agency's responsibilities with regard to the selection and training of astronauts; RECALLS that the European Astronauts Centre was created with the specific responsibility of fulfilling those functions; NOTES that the costs corresponding to the Columbus Programme's requirements in this respect are covered by the said programme; and NOTES further that the role and funding of the Centre will be reviewed in 1995 in line with the complementary decisions to be taken by the end of 1995 with regard to crewed space activities.

D. The Hermes Programme

1. NOTES the decision taken by the States participating in the Hermes Programme that the work undertaken in 1992 pursuant to the decision taken on 20 November 1991 by Council meeting at Ministerial Level entails completion of Phase 1 of the Hermes Programme on 31 December 1992.

2. NOTES that the Hermes Programme, as defined in the Director General's proposal referred to in the preamble, introduces a reorientation period of three years from 1 January 1993 for the purpose of studying the following three strategic options for implementation of a future crewed transportation system:
   - cooperation with Russia
   - cooperation with the United States
   - an autonomous European scenario

   and comprises the following activities:

   (1) system studies, primarily directed towards definition of an ESA–Russian Hermes crew transportation vehicle, and development of critical technologies based on the Hermes definition, for an estimated amount of 338 MAU at mid-1991 economic conditions;
   (2) a detailed definition study for the ESA Assured Crew Return Vehicle (ACRV), as an element of cooperation with the United States relating to the International Space Station, for an estimated amount of 45 MAU at mid-1991 economic conditions;
   (3) detailed definition studies and pre-development of servicing elements, for an estimated amount of 94 MAU at mid-1991 economic conditions.

3. NOTES the decision of the States participating in the Hermes Programme to execute the programme reorientation activities with an overall corresponding financial envelope estimated at 567 MAU at mid-1991 economic conditions, including 90 MAU for commitments made during Phase 1 of the programme, it being understood that the corresponding envelope will be financed with regard to activities undertaken as of 1 January 1993 in accordance with the overall contribution scale in Table I attached hereto and that the Participating States' contributions will be called up in accordance with the separate contribution scales correspondimg to the activities described under Section 2 above.

4. INVITES the States participating in the Hermes Programme to include in the corresponding Declaration suitable provisions for the decisions to be taken on the development of the crewed transport system and the servicing elements selected in the course of the three-year reorientation period from 1993 to 1995, and INVITES the Director General to prepare a final proposal as a basis for the required complementary decisions in 1995.

4. INVITE le Directeur général à prendre les mesures appropriées comprenant éventuellement la prolongation d'un an au maximum de la réalisation du laboratoire raccordé Columbus afin de concilier les impératifs du programme avec les ressources financières mises à disposition par les Etats participants selon le tableau I ci-joint.

5. PREND bonne note des premières informations fournies dans la proposition du Directeur général visée au préambule sur les coûts envisagés et sur les principes de partage des coûts du programme d'exploitation du laboratoire raccordé Columbus et INVITE le Directeur général à formuler une proposition finale en ce sens afin qu'une décision sur ledit programme d'exploitation puisse être prise en temps opportun.

6. INVITE les Etats participant au programme Columbus à suivre de près la façon dont se déroule le développement de la Station spatiale internationale et, le cas échéant, à prendre des décisions sur les ajustements à apporter au programme.

7. RECONNAIT à l'Agence la responsabilité de la sélection et de la formation des astronautes; RAPPELLE que le Centre des astronautes européens a été créé spécifiquement pour assumer ces fonctions; NOTE que les coûts correspondant au besoins du programme Columbus à cet égard sont couverts par ledit programme; et NOTE en outre que le rôle et le financement de ce Centre seront réexaminés en 1995 en fonction des décisions complémentaires à prendre avant la fin de 1995 au sujet des activités spatiales avec équipage.

D. Le programme Hermes

1. PREND NOTE de la décision des Etats participant au programme Hermes selon laquelle les travaux entrepris en 1992 en application de la décision prise le 20 novembre 1991 par le Conseil siégeant au niveau ministériel conduisent à l'achèvement de la phase-1 du programme Hermes le 31 décembre 1992.

2. NOTE que le programme Hermes, tel qu'il est défini dans la proposition du Directeur général visée au préambule, prévoit, à partir du 1er janvier 1993, une réorientation d'une durée de trois ans en vue d'étudier les trois options stratégiques suivantes pour la mise en oeuvre d'un futur système de transport avec équipage:
   - coopération avec la Russie
   - coopération avec les Etats-Unis
   - scénario européen autonome

   et porte sur les activités suivantes:

   (1) études système axées principalement sur la définition d'un véhicule de transport d'équipage Hermes ESA–Russie et mise au point de technologies critiques basées sur la définition d'Hermes, pour un montant estimé à 338 MUC aux conditions économiques de la mi-1991;

   (2) étude de définition détaillée du véhicule de secours pour le retour de l'équipage (ACRV) de l'ESA en tant qu'élément réalisé dans le cadre de la coopération avec les Etats-Unis au sujet de la Station spatiale internationale pour un montant estimé à 45 MUC aux conditions économiques de la mi-1991;

   (3) études de définition détaillée et travaux de prédéveloppément portant sur des éléments de desserte pour un montant estimé à 94 MUC aux conditions économiques de la mi-1991.

3. PREND NOTE de la décision des Etats participant au programme Hermes d'excuter les activités de réorientation du programme dans les limites d'une enveloppe financière globale correspondante estimée à 567 MUC aux conditions économiques de la mi-1991, ce chiffre comprenant une somme de 90 MUC pour les engagements pris au cours de la phase-1 du programme, étant entendu que l'enveloppe correspondante sera financée, en ce qui concerne les activités entreprises à partir du 1er janvier 1993, conformément au barème général de contributions qui figure au tableau I ci-joint et que les contributions des Etats participants seront appelées conformément aux barèmes de contributions distincts correspondant aux activités décrites au paragraphe 2 ci-dessus.

CHAPTER III
Review of the In-Orbit Infrastructure Programmes: Columbus Attached Laboratory, DRS, Hermes

1. AGREES to proceed in February 1995 to a review of the infrastructure programmes referred to in Chapter II above, on the basis of a report of the Director General concerning the status of their execution and the results of the negotiations he will have conducted with international partners.

2. HAVING REGARD to the Intergovernmental Agreement and the Memorandum of Understanding concluded on the International Space Station, INVITES the Director General to negotiate with NASA the terms of an agreement on the allocation of the exploitation costs of the International Space Station which will satisfy the following requirements:
   - a commitment by NASA that the Agency contribution to the Space Station annual common system operations costs will remain under a firm fixed financial ceiling;
   - a commitment by NASA to the effect that a significant portion of the said Agency's contribution shall be made through the provision of goods and service in kind, such as the Assured Crew Return Vehicle (ACRV), the Automated Transfer Vehicle (ATV) using the Ariane launcher and the Data Relay System (DRS), so as to minimise the exchange of funds.

3. INVITES the States participating in the Columbus Attached Laboratory element of the Columbus Programme to decide, by a two-thirds majority representing at least two-thirds of the contributions to the programme, the unblocking of the amount of 350 MAU, earmarked for preparation of utilisation and operations, referred to in Section 3 of Chapter IIC.

4. INVITES the Member States to agree, on the basis of a proposal of the Director General, principles for the financing of the exploitation costs of the Columbus Attached Laboratory.

5. INVITES the Director General to negotiate with Russia the terms of an agreement on the joint development of a crewed space transportation system and to report on the status of these negotiations to the Participating States concerned in time for the review referred to in Section 1 above.

6. INVITES the States participating in the Hermes Programme to determine, on the basis of this report, if the terms and conditions negotiated respectively with Russia and the United States permit the decision to be made on the options identified in Section 2 of Chapter IID.

7. INVITES the States participating in the DRS Programme Element to decide, by a two-thirds majority representing at least two-thirds of the contributions to the programme, the integration of the second flight unit, and to decide the launch of the said unit by a unanimous vote, as referred to in Section 2 of Chapter IIB.

CHAPTER IV
Other Programmes

STRESSING the need to explore with Member States ways in which the development and launching of small satellites could contribute to fulfilment of the objectives outlined in the Long-Term Space Plan with regard to all the sectors of space activities referred to in this chapter.

CONSIDERING that the private sector involvement in the utilisation of available resources, and in financing and operating responsibilities, is to be encouraged,

A. Science Programme

REAFFIRMS its support for the Science Programme and for full and timely implementation of the Horizon 2000 Programme, in accordance with the provisions of Resolution ESA/C/XCIII/Res.2 (Final) of 13 December 1990 and RECOGNISES that the Horizon 2000 programme, by furthering understanding of the Universe through space astronomy and in-situ exploration of the solar system, is the key element in implementing European space science policy; and INVITES the Director General to submit in 1995, taking

4. INVITE les Etats participant au programme Hermes à inclure dans la Déclaration correspondante des dispositions adéquates au sujet des décisions à prendre sur le développement du système de transport avec équipage et des éléments de desserte choisis au cours de la période de réorientation de trois ans de 1993 à 1995; et INVITE le Directeur général à préparer une proposition finale devant servir de base aux décisions complémentaires à prendre en 1995.

CHAPITRE III
Examen des programmes d'infrastructure orbitale: laboratoire raccordé Columbus, DRS, Hermes

1. CONVIENT de procéder en février 1995 à un examen des programmes d'infrastructure visés au chapitre II ci-dessus, sur la base d'un rapport du Directeur général relatif à l'état d'avancement de leur exécution et aux résultats des négociations qu'il aura conduites avec les partenaires internationaux.

2. VU l'Accord intergouvernemental et le Mémorandum d'Accord conclus sur la Station spatiale internationale, INVITE le Directeur général à négocier avec la NASA les termes d'un accord relatif à une affectation des coûts d'exploitation de la Station spatiale internationale propre à répondre aux impératifs suivants:
   - engagement de la NASA aux termes duquel la contribution de l'Agence aux coûts communs annuels d'exploitation des systèmes de la Station spatiale restera en-deçà d'un plafond financier forfaitaire définitif;
   - engagement de la NASA conduisant à ce qu'une part significative de ladite contribution de l'Agence soit apportée sous la forme de biens et de services fournis en nature tels que le véhicule de secours pour le retour de l'équipage (ACRV), le véhicule de transfert automatique (ATV) faisant appel au lanceur Ariane et le système de relais de données (DRS), afin de réduire au minimum les échanges de fonds.

3. INVITE les Etats participant à l'élément laboratoire raccordé Columbus du programme Columbus à décider, à une majorité des deux tiers représentant au moins deux tiers des contributions au programme, le déblocage du montant de 350 MUC visé au point 3 du chapitre IIC, réservé à la préparation de l'utilisation et de l'exploitation.

4. INVITE les Etats membres à convenir, sur la base d'une proposition du Directeur général, de principes relatifs au financement des coûts d'exploitation du laboratoire raccordé Columbus.

5. INVITE le Directeur général à négocier avec la Russie les termes d'un accord relatif à la réalisation en commun d'un système de transport spatial habité et à rendre compte aux Etats participants intéressés de l'état d'avancement de ces négociations en temps voulu pour l'examen visé au point 1 ci-dessus.

6. INVITE les Etats participant au programme Hermes à vérifier, sur la base de ce rapport, si les conditions négociées respectivement avec la Russie et les Etats-Unis permettent de prendre une décision sur les options mentionnées au point 2 du chapitre IID.

7. INVITE les Etats participant à l'élément de programme DRS à décider, à une majorité des deux tiers représentant au moins deux tiers des contributions au programme, de l'intégration et du lancement de la deuxième unité de vol, et à décider du lancement de ladite unité par un vote à l'unanimité, comme il est dit au point 2 du chapitre IIB.

CHAPITRE IV
Autres programmes

SOULIGNANT la nécessité de rechercher avec les Etats membres par quels moyens la réalisation et le lancement de petits satellites pourraient contribuer à atteindre les objectifs exposés dans le plan spatial à long terme pour tous les secteurs des activités spatiales visés au présent chapitre,

CONSIDERANT qu'il convient d'encourager la participation du secteur privé à l'utilisation des ressources disponibles ainsi qu'à l'exercice de responsabilités en matière de financement et d'exploitation, account of scientific, technical and political developments and after consultation with the scientific community, a plan for the continuing implementation of European space science policy.

B. Earth-Observation Programmes

1. RECOGNISES the need to start the Meteosat Second Generation Programme in 1993 on the basis of the Director General's programme proposal, taking into account the terms of the agreement to be concluded concerning Eumetsat's participation, and INVITES interested Member States to establish the necessary legal instruments.

2. INVITES the Director General to submit in 1993 to Member States a programme proposal concerning an Earth observation data user programme.

3. RECALLS the interest expressed by the scientific community in the Aristoteles programme as described in the Long-Term Space Plan and RECOGNISES the need to continue minimum activities to allow for execution of the said programme.

C. Microgravity Programme

AGREES that the States participating in the Microgravity Programme shall proceed with the reorganisation of the said programme to include the following two elements:

(a) a basic microgravity research programme (EMIR) dedicated to scientific use of the microgravity environment;
(b) a programme to develop the facilities required for microgravity experiments to be carried out in the Columbus Attached Laboratory.

D. Telecommunications Programme

1. AGREES the principle of continuing the activities previously undertaken within the Payload and Spacecraft Development and Experiments (PSDE) Programme and the Advanced Systems and Technology Programme (ASTP); NOTES the findings of the Agency's working group on satellite telecommunications policy, which stress the far-reaching implications for European industry of the European Commission's plan for deregulation in this economic sector; and CALLS for close consultation with operators, regulatory authorities and industry in order to implement a consistent policy for improving the competitiveness of the European telecommunications industry.

2. NOTES the strategy described in the Director General's proposal referred to in the preamble, which seeks to achieve greater coherence in the Agency's telecommunications activities and to merge as far as possible programmes and activities referred to in Paragraph 1 within a unified programme on Advanced Research in Telecommunications Systems (ARTES); INVITES the interested States to establish the necessary legal instruments and to indicate as soon as possible their level of participation.

E. Launcher Programmes

1. RECOGNISES the need for continuous research and technology accompaniment activities during the operational lifetime of the Ariane launchers, so as to ensure their technical reliability and performance, as a responsibility shared between the design authority and industry, and WELCOMES the Director General's proposals in this respect; and AGREES in principle to set up before the end of 1995 the programmes necessary for ensuring an orderly transition from Ariane-4 to Ariane-5, as well as those which are required to permit further evolution of the Ariane 5 launcher's capabilities.

2. RECOGNISES that the Guiana Space Centre (CSG) is an essential element in the Agency's strategy and EXPRESSES its willingness to continue to build on the experience gained from exploitation of the CSG for the benefit of the Agency's programmes;
   RECALLING the report presented to Council by the Director General on 8 November 1992 on the present status of the discussions held with CNES on the execution of the CSG activities beyond 1992,

A. Programme scientifique

REAFFIRME son soutien au programme scientifique et à la mise en oeuvre, en temps opportun, de l'intégralité du programme Horizon 2000 conformément aux dispositions de la Résolution ESA/C/XCIII/Rés. 2 (Final) du 13 décembre 1990, et RECONNAIT que le programme Horizon 2000, parce qu'il améliore notre connaissance de l'univers par l'astronomie spatiale et l'exploration in situ du système solaire, est l'élément clé de la mise en oeuvre de la politique européenne en matière de science spatiale, et INVITE le Directeur général à soumettre en 1995, compte tenu du contexte scientifique, technique et politique, et après consultation de la communauté scientifique, un plan ayant pour objet la poursuite de la mise en oeuvre de la politique européenne en matière de science spatiale.

B. Programmes d'observation de la Terre

1. RECONNAIT la nécessité de mettre en route en 1993 le programme Météosat de deuxième génération sur la base de la proposition de programme du Directeur général, compte tenu des termes de l'accord à conclure au sujet de la participation d'Eumetsat, et INVITE les Etats membres intéressés à établir les instruments juridiques nécessaires.

2. INVITE le Directeur général à soumettre aux Etats membres en 1993 une proposition de programme relative à un programme pour les utilisateurs de données d'observation de la Terre.

3. RAPPELLE l'intérêt manifesté par la communauté scientifique à l'égard du programme Aristoteles, tel qu'il est présenté dans le Plan spatial à long terme et RECONNAIT la nécessité de poursuivre un minimum d'activités en vue de permettre l'exécution dudit programme.

C. Programme de recherche en microgravité

CONVIENT que les Etats participant au Programme de recherche en microgravité procéderont à la restructuration de ce programme afin d'y inclure les deux éléments suivants:

(a) un programme de recherche fondamentale en microgravité (EMIR) axé sur l'utilisation scientifique des conditions de quasi-impesanteur;

(b) un programme ayant pour objet de réaliser les équipements nécessaires aux expériences en microgravité à mener à bord du laboratoire raccordé Columbus.

D. Programme de télécommunications

1. APPROUVE le principe d'une poursuite des activités déjà entreprises dans le cadre du programme de développement et d'expérimentation de charges utiles et de véhicules spatiaux (PSDE) et du programme de systèmes et de technologies de pointe (ASTP); PREND NOTE des conclusions du Groupe de travail ESA sur la politique de télécommunications par satellite qui soulignent l'étendue des conséquences pour l'industrie européenne du projet de déréglementation de la Commission des communautés européennes dans ce secteur économique; et DEMANDE une concertation étroite avec les exploitants, les autorités réglementaires et l'industrie afin de mettre en oeuvre une politique cohérente visant à améliorer la compétitivité de l'industrie des télécommunications européenne.

2. PREND NOTE de la stratégie exposée dans la proposition du Directeur général visée au préambule, visant à renforcer la cohérence des activités de l'Agence en matière de télécommunications et à fusionner, dans la mesure du possible, les programmes et activités visés au paragraphe 1 dans le cadre d'un programme unique de recherche de pointe sur les systèmes de télécommunications (ARTES); INVITE les Etats intéressés à établir les instruments juridiques nécessaires et à faire connaître dès que possible le niveau de leur participation.

E. Programmes de lanceurs

1. RECONNAIT la nécessité de mener sans interruption des activités d'accompagnement de recherche et de technologie pendant la durée de vie opérationnelle des lanceurs Ariane de manière à garantir leur capacité d'emport et leur fiabilité technique au titre d'une responsabilité partagée par l'autorité de conception et l'industrie, et ACCUEILLE FAVORABLEMENT les propositions soumises à cet égard par

INVITES the Directors General of the Agency and of CNES to finalise the terms of an agreement on the continued funding of the CSG beyond 1992 and submit it to the Agency's relevant bodies with a view to early approval by Council at Delegate Level.

3. INVITES the Member States to pursue their efforts to define the Future European Space Transportation Investigation Programme (FESTIP) so that a decision on its start-up can be taken as soon as possible.

F. Technology

WELCOMES the approval by Council at its 103 rd Meeting of the Resolution on the General Support Technology Programme (GSTP), ESA/C/CIII/Res. 1 (Final), and INVITES Member States to subscribe expeditiously to the corresponding programme Declaration.

CHAPTER V
European Launcher Policy

WHEREAS the Ariane launcher developed by the Agency is a strategic asset providing Europe with autonomous access to space and must be preserved as a vital component of European space policy and of the Long-Term Space Plan,

1. REAFFIRMS the principles of European space launcher policy laid down in Resolution ESA/C/CIII/Res. 2 (Final), adopted on 23 October 1992.

2. INVITES the Member States to implement the principle of granting preference to the Ariane launcher for their own missions and those of European and international bodies in which they participate in accordance with the provisions of the Declaration on the production phase renewed on 21 May 1992 and to encourage the satellite operators, which they have entrusted with the task of meeting the needs of the general public in fields such as telecommunications, also to grant preference to the Ariane launcher.

3. INVITES the Director General to submit proposals designed to further the principle of European preferential use of the Ariane launchers.

4. INVITES the Director General to contribute in close cooperation with both the Member States and the competent bodies of European Communities, to the conclusion of an agreement, or other form of terms and conditions, with the governments of other space-faring nations to ensure fair conditions in the launcher market.

CHAPTER VI
Industrial Policy

RECALLING the objectives of the Agency's industrial policy as set out in Article VII of the Convention, namely to meet the requirements of the European space programme in a cost-effective manner, to improve the worldwide competitiveness of European industry, to ensure that all Member States participate in an equitable manner in implementing the European space programme, and to exploit the advantages of free competitive bidding,

1. CONSIDERING the industrial impact of the reorientation called for in the Director General's proposal, DECIDES that the lower limit for the cumulative return coefficient referred to in Article IV.6 of Annex V to the Convention, below which special measures are to be taken in accordance with Article V of that Annex, be maintained at 0.95 for the present three-year period (1991–93) and be fixed at 0.96 for the following period (1994–96), it being understood that the objective continues to be to achieve an overall return coefficient as near as possible to the ideal value of 1 for all countries.

2. REAFFIRMS the guidelines and measures concerning the Agency's industrial policy which were decided upon by Council meeting at Ministrial Level in The Hague in 1987 and in Munich in 1991, INVITES the Director General, in consultation with Member States, to further evaluate and formulate

le Directeur général; et, de plus, CONVIENT en principe d'instaurer avant la fin de 1995 les programmes propres à assurer une transition méthodique entre Ariane-4 et Ariane-5 ainsi que les programmes nécessaires à l'évolution ultérieure des capacités du lanceur Ariane-5.

2. RECONNAIT que le Centre spatial guyanais (CSG) est un élément essentiel de la stratégie de l'Agence et EXPRIME sa volonté de continuer à tirer parti de l'expérience acquise dans le cadre de l'exploitation du CSG au bénéfice des programmes de l'Agence.

   RAPPELANT le rapport présenté au Conseil par le Directeur général le 8 novembre 1992, qui fait le point des discussions conduites avec le CNES au sujet de l'exécution des activités du CSG au delà de 1992, INVITE les Directeurs généraux de l'Agence et du CNES à arrêter les modalités d'un accord relatif à la poursuite du financement du CSG au-delà de 1992 et à soumettre cet accord aux organes compétents de l'Agence en vue de son approbation rapide par le Conseil au niveau des délégués.

3. INVITE les Etats membres à poursuivre leur action visant à définir le programme européen de recherche appliquée sur les futurs systèmes de transport spatial (FESTIP) afin qu'une décision sur sa mise en route puisse être prise le plus tôt possible.

F. Technologie

ACCUEILLE FAVORABLEMENT l'approbation par le Conseil, lors de sa 103ème session, de la Résolution habilitante relative au programme général de technologie de soutien (GSTP), ESA/C/CIII/Rés.1 (Final), et INVITE les Etats membres à souscrire rapidement à la Déclaration de programme correspondante.

CHAPITRE V
Politique en matière de lanceurs européens

CONSIDERANT que l'Europe dispose, avec le lanceur Ariane réalisé par l'Agence, d'un atout stratégique pour un accès autonome à l'espace et que ce lanceur doit rester un élément essentiel de la politique spatiale européenne et du Plan spatial à long terme,

1. REAFFIRME les principes de la politique européenne en matière de lanceurs énoncés dans la Résolution ESA/C/CIII/Rés. 2 (Final), adoptée le 23 octobre 1992.

2. INVITE les Etats membres à appliquer, conformément aux dispositions de la Déclaration relative à la phase de production, renouvelée le 21 mai 1992, le principe consistant à se servir en priorité du lanceur Ariane pour la conduite de leurs propres missions et des missions d'organismes européens ou internationaux auxquelles ils participent et à encourager les exploitants de satellites à qui ils ont confié la mission de répondre aux besoins du grand public dans des domaines comme celui des télécommunications, à accorder également la préférence au lanceur Ariane.

3. INVITE le Directeur général à soumettre des propositions visant à promouvoir le principe de la préférence européenne pour l'utilisation des lanceurs Ariane.

4. INVITE le Directeur général à contribuer, en collaboration étroite avec les Etats membres et les organes compétents des Communautés européennes, à la conclusion avec les gouvernements d'autres puissances spatiales d'un accord ou autre forme d'arrangement garantissant des conditions équitables sur le marché des lanceurs.

CHAPITRE VI
Politique industrielle

RAPPELANT les objectifs de l'Agence en matière de politique industrielle énoncés à l'article VII de la Convention, à savoir répondre aux besoins du programme spatial européen d'une manière économiquement efficiente, améliorer la compétitivité de l'industrie européenne dans le monde, garantir que tous les Etats membres participent de façon équitable à la mise en oeuvre du programme spatial européen, et bénéficier des avantages de l'appel à la concurrence, proposals in this respect, in particular proposals to minimise the overall surplus and deficit situations, in order to allow the Industrial Policy Committee and Council to take the appropriate decisions and STRESSES that, when establishing and implementing procedures for fulfilling industrial policy objectives, the particular situation of each Member State's industrial infrastructure shall be given due consideration.

3. INVITES States participating in the Columbus and Hermes Programmes to insert in the relevant programme Declarations provisions allowing for the application of the appropriate measures to correct imbalances recorded in the programmes at the end of 1992, bearing in mind the provisions of Section 1 above with regard to the cumulative return coefficient, and ensuring that all Participating States have a guaranteed return coefficient of 0.9 at programme completion.

CHAPTER VII
General Provisions

NOTING with satisfaction the statements made by Delegations at the present Council Meeting regarding their participation in the programmes referred to in Chapter II, together with the scales of contributions in Table I attached hereto,

WHEREAS it is essential to take measures at an early date that will ensure programmatic and financial continuity in the execution of the Agency's programmes,

RECALLING that the present Resolution introduces a reorientation period for the purpose of evaluating new opportunities for international cooperation and preparing for the adoption, before the end of 1995, of complementary decisions that will be needed to ensure satisfactory execution of a number of the Agency's optional programmes,

A. Transitional Measures

1. URGES the States participating in the programmes referred to in Chapter II to adopt, by the end of 1992, the corresponding 1993 budgets on the basis of the present Resolution, which shall thus constitute the legal basis for their adoption and execution until adoption of the corresponding amended programme Declarations, using the financial envelopes and scales of contributions contained in this Resolution.

2. INVITES the States participating in the programmes concerned to complete their revision of the corresponding Declarations by 31 March 1993 at the latest on the basis of this Resolution so as to ensure the necessary continuity of the said programmes.

3. AUTHORISES the Director General to take without delay the action needed to begin implementation of each of the programmes concerned, while taking care not to commit the Agency beyond 1993 budgets as long as the corresponding Declaration referred to in Section 2 above is not finalised and entered into force.

B. Other General Provisions

1. INVITES the Director General to implement the provisions of his proposal referred to in the preamble pertaining to the Agency's ground infrastructure and to pursue the definition of that infrastructure, making the best use of existing facilities and available services of the Agency and of Member States as a first priority, and of those of the Associate Member and Cooperating States in accordance with the applicable arrangements; and further INVITES the Director General to formulate proposals in due course with a view to establishing the basis for any decisions that may be required in this respect, including the complementary decisions to be taken by the end of 1995.

2. RECOGNISES that the size and importance of the major optional programmes together with the budgetary constraints experienced by Member States call for further efforts in improving the management of these programmes; DECIDES to set up a Council Working Group to examine proposals for improving the supply of information to Participating States concerning the execution of the said programmes and for handling any structural deficits that may arise in their financial coverage; the

1. CONSIDERANT les conséquences pour l'industrie de la réorientation demandée dans la proposition du Directeur général, DECIDE que la limite inférieure du coefficient de retour cumulé mentionnée à l'article IV, paragraphe 6 de l'Annexe V de la Convention, en deçà de laquelle des mesures spéciales doivent être prises en application de l'article V de ladite Annexe, sera maintenue à 0,95 pour la période triennale actuelle (1991–1993) et sera fixée à 0,96 pour la période suivante (1994–1996), étant entendu que l'objectif visé demeure de faire bénéficier tous les pays d'un coefficient de retour aussi proche que possible de la valeur idéale égale à l'unité.

2. REAFFIRME les lignes directrices et les mesures relatives à la politique industrielle de l'Agence, qui ont été arrêtées par le Conseil siégeant au niveau ministériel à La Haye en 1987 et à Munich en 1991; INVITE le Directeur général à poursuivre en concertation avec les Etats membres l'évaluation et la formulation de propositions allant dans ce sens, et en particulier de propositions tendant à réduire au maximum les situations d'excédent ou de déficit global, afin de permettre au Comité de la politique industrielle et au Conseil de prendre les décisions appropriées; et SOULIGNE que lors de l'établissement et de la mise en oeuvre des procédures visant à atteindre les objectifs de politique industrielle, il sera tenu dûment compte de la situation particulière de l'infrastructure industrielle de chacun des Etats membres.

3. INVITE les Etats participant aux programmes Columbus et Hermes à insérer, dans les Déclarations de programme correspondantes, des dispositions prévoyant les mesures spécifiques à appliquer pour corriger les déséquilibres enregistrés dans ces programmes à la fin de 1992, en tenant compte des dispositions du paragraphe 1 ci-dessus relatives au coefficient de retour cumulé et garantissant à tous les Etats participants un coefficient de retour de 0,9 à l'achèvement du programme.

CHAPITRE VII
Dispositions générales

PRENANT NOTE avec satisfaction des déclarations faites par les Délégations à la présente session du Conseil au sujet de leur participation aux programmes visés au Chapitre II ainsi que des barèmes de contributions figurant au tableau I ci-joint,

CONSIDERANT qu'il est indispensable de prendre à une date proche des mesures garantissant, au niveau programmatique et financier, la continuité d'exécution des programmes de l'Agence,

RAPPELANT que la présente Résolution instaure une période de réorientation ayant pour objet d'évaluer de nouvelles possibilités de coopération internationale et de mener des activités préparatoires en vue d'adopter, avant la fin de 1995, les décisions complémentaires nécessaires pour garantir la bonne exécution d'un certain nombre de programmes facultatifs de l'Agence,

A. Mesures transitoires

1. INVITE INSTAMMENT les Etats participant aux programmes visés au Chapitre II à adopter, avant la fin de 1992, les budgets 1993 correspondants sur la base de la présente Résolution, qui constituera donc le fondement juridique de leur adoption et de leur exécution jusqu'à l'adoption des Déclarations de programme amendées correspondantes, et ce en utilisant les enveloppes financières et les barèmes de contributions figurant dans la présente Résolution.

2. INVITE les Etats participant aux programmes en cause à procéder le 31 mars 1993 au plus tard à la révision des Déclarations correspondantes sur la base de la présente Résolution, de façon à garantir la continuité indispensable desdits programmes.

3. AUTORISE le Directeur général à prendre sans tarder les mesures nécessaires pour mettre en route l'exécution de chaque programme concerné tout en prenant soin de ne pas engager l'Agence au-delà des budgets de 1993 tant que la déclaration correspondante, visée au point 2 ci-dessus, n'aura pas été définitivement arrêtée et ne sera pas entrée en vigueur.

working group shall also examine proposals aiming at reconciling the budgetary planning of Member States with the efficient and timely execution of these programmes with a view, in particular, to accommodating those Member States that need to contain their annual contributions within predetermined financial limits; REQUESTS the working group to submit its findings to Council before 28 February 1993; INVITES the States participating in the programmes concerned to incorporate in the corresponding Declarations the measures adopted by Council, taking into account the specific features of each programme; AGREES that the process described above shall not prejudge the finalisation and entry into force of the said Declarations pursuant to Section A2 above.

3. RECOGNISES that the existing system of the Agency to adjust contributions for variations in conversion rates should be modified in order to cope with monetary fluctuations more effectively; AGREES to decide at its next session at delegate level in December 1992 on interim measures to address the effects in 1992 and 1993 of the recent monetary fluctuations until a fully modified system and its adoption procedures have been agreed upon; and INVITES the Director General to make a proposal to the said Council session, taking due note of the views expressed during this session, and which shall be based in particular on the following alternative solutions already described, among others, in document ESA/C(92)92:
   - in the first instance, to apply the retroactive adjustment to a State's contributions only to the extent that amounts are not actually spent in the State concerned.
   - to apply a 50% abatement on adjustments of contributions both on the payments to the Agency as well as on reimbursement by the Agency;

   DECIDES to set up a Council Working Group in order to report before the end of 1993 with a view to proposing a reform of the Agency's adjustments mechanism towards a more complete and equitable system.

4. INVITES the Director General to assist the scientific community active in the field of Earth observation in the definition of its priorities and to explore in due course, in consultation with Member States and Finland, the possibility of incorporating the science and research parts of the Earth-Observation Programme in the Agency's mandatory activities, and to make proposals to Council to that effect; and further INVITES the Director General to pursue similar actions as appropriate with regard to the field of microgravity.

5. DECIDES to consider the complementary decisions required for the programmes referred to in Chapter II of this Resolution at a meeting at Ministerial Level to be held in 1995.

B. Autres dispositions générales

1. INVITE le Directeur général à mettre en oeuvre les dispositions de sa proposition visée au préambule relatives à l'infrastructure sol de l'Agence et à poursuivre la définition de cette infrastructure, en faisant le meilleur usage possible, en priorité, des moyens existants et des services disponibles à l'Agence et chez les Etats membres, puis de ceux des Etats membres associés et coopérants, selon les arrangements en vigueur; INVITE en outre le Directeur général à formuler, en temps opportun, des propositions visant à jeter les bases de toute décision pouvant se révéler nécessaire à cet égard, y compris les décisions complémentaires qui doivent être prises avant la fin de 1995.

2. RECONNAIT que la taille et l'importance des grands programmes facultatifs ainsi que les contraintes budgétaires rencontrées par les Etats membres demandent des efforts supplémentaires pour améliorer la gestion desdits programmes; DECIDE de créer par la présente Résolution un groupe de travail du Conseil chargé d'examiner des propositions visant à améliorer la communication aux Etats participants des informations sur l'exécution desdits programmes et à faire face à tout déficit structurel qui pourrait survenir dans leur couverture financière; le groupe de travail examinera également des propositions visant à concilier la planification budgétaire des Etats membres et l'exécution de ces programmes de façon efficace et dans les délais, en vue notamment de tenir compte des Etats membres qui doivent maintenir leurs contributions annuelles dans le cadre de limites financières prédéterminées; DEMANDE au groupe de travail de soumettre ses conclusions au Conseil avant le 28 février 1993; INVITE les Etats participant aux programmes concernés à intégrer dans les Déclarations correspondantes les mesures retenues par le Conseil, en tenant compte de la spécificité de chaque programme; CONVIENT que le processus décrit ci-dessus se déroulera sans préjudice de la mise en forme définitive et de l'entrée en vigueur desdites Déclarations en application du point A(2) ci-dessus.

3. RECONNAIT qu'il faudrait modifier le système actuel de l'Agence concernant l'ajustement des contributions pour cause de variations des taux de conversion pour pouvoir réagir plus efficacement aux fluctuations monétaires; CONVIENT de décider lors de sa prochaine session au niveau des délégués, en décembre 1992, de mesures intérimaires ayant trait aux effets des récentes fluctuations monétaires en 1992 et 1993 jusqu'à ce qu'il ait été convenu d'un système entièrement modifié et de ses procédures d'adoption; et INVITE le Directeur général à faire, lors de ladite session du Conseil, une proposition prenant bonne note des vues exprimées au cours de la présente session et qui se fondera notamment sur l'alternative suivante, déjà exposée entre autres dans le document ESA/C(92)92:
   - en premier lieu, appliquer l'ajustement rétroactif aux contributions d'un Etat uniquement pour les montants qui n'ont pas été effectivement dépensés dans l'Etat en cause;
   - appliquer un abattement de 50% sur les ajustements des contributions, tant en ce qui concerne les paiements à l'Agence que les remboursements par l'Agence;

   DECIDE de créer un Groupe de travail du Conseil chargé de faire rapport avant la fin de 1993 en vue de proposer une réforme du mécanisme d'ajustement en vigueur à l'Agence devant aboutir à un système plus complet et équitable.

4. INVITE le Directeur général à accorder son soutien à la communauté scientifique oeuvrant dans le domaine de l'observation de la Terre pour ce qui est de définir ses priorités et à explorer en temps opportun, en concertation avec les Etats membres et avec la Finlande, la possibilité d'incorporer les activités scientifiques et de recherche du programme d'observation de la Terre dans les activités obligatoires de l'Agence, et à faire au Conseil des propositions à cet effet; et INVITE en outre le Directeur général à mener, en fonction de la situation, des actions similaires dans le domaine de la microgravité.

5. DECIDE d'examiner les décisions complémentaires requises par les programmes visés au Chapitre II de la présente Résolution qui devront être prises à une session au niveau ministériel devant se tenir en 1995.

TABLE I

The Delegations declare that their respective States will participate as follows in the programmes referred to in Chapter II of this Resolution and will ensure the continuation of the said programmes on the basis of the corresponding amended Declarations, it being understood that full financial coverage for the Agency's programmes is essential for their orderly execution:

A. The POEM-1 Programme

Participant	Envisat-1 Mission %	Metop-1 Preparation %
Austria	1.00	1.00
Belgium	4.00	4.00
Denmark	0.5–1.00	0.5–1.00
France	25.00	25.00
Germany	17.40	18–22.00
Italy	12.00	16.00
Netherlands	2.14	4.60
Norway	1.30	1.50
Spain	7.00–8.00	7.00–8.00
Sweden	5.10	3.35
Switzerland	4.00	4.00
United Kingdom	21–25.00	14.60
Canada	2.7–5.00	—
Finland	1.20	—
TOTAL	104.34–112.14	99.55–105.05

B. The DRS Element of the DRTM Programme

Participant	Scale, %
Austria	1.50
Belgium	4.00
France	[20.00]
Germany	12.00
Italy	45.00
Netherlands	2.00
Spain	up to 4.00
Sweden	1.80
Switzerland	0.10*
United Kingdom	1.00
Finland	0.40
TOTAL	up to 91.80

* This figure corresponds to the Swiss contribution of 2% to the former Phase 1 of the DRS Programme Element of the DRTM Programme

C. The Columbus Programme

Participant	Attached Laboratory %	Polar Platform %	Precursor Flights %	Future Station %	Overall Average %
Austria	—	—	[1.00]	—	0-09
Belgium	3.80	9.45	5.00	3.02	5.00
Denmark	1.00	1.00	1.00	1.00	1.00
France	10.00	23.60	[10.00]	[20.00]	12.74
Germany	38.00	17.80	15.00	35.0	31.99
Italy	31.00	8.80	14.00	12.00	25.00
Netherlands	0.50	4.00	1.00-3.00	4.00	1.26–1.43
Norway	0.48	0.30	—	—	0.40
Spain	up to 3.00	up to 6.00	—	—	0–3.29
Sweden	1.00	1.00	—	—	0.90
Switzerland	—	—	[2.00]	—	0.18
UK	up to 1.00	22.60	—	—	4.41–5.12
TOTAL	up to 89.78*	up to 94.55	49–51.00	75.02	

* The shortfall will be covered in the following manner: a) savings representing 5% of the financial envelope of 2516.8 MAU, and b) voluntary additional contributions to bring the covered portion to 95% of the said financial envelope; it is understood also that the actual level of contributions to be paid by the participating States concerned for the period 1993–1995 shall not be affected by the increased contributions scale.

D. The Hermes Programme

Participant	Overall Scale %
Austria	[0.50]
Belgium	5.80
Denmark	0.45
France	43.50
Germany	22.00
Italy	12.10
Netherlands	6.00
Spain	up to 4.10
Sweden	0.50
Switzerland	2.00
Canada	2.00
TOTAL	up to 98.95

Resolution on International Cooperation

adopted on 10 November 1992

The Council meeting at Ministerial Level,

HAVING REGARD to Resolution ESA/C-M/XCVII/Res. 1 (Final) on the European Long-Term Space Plan and programmes, adopted in Munich on 20 November 1991, which reaffirmed the need to intensify international cooperation, taking into account the evolution of the geopolitical context, with a view to achieving fully the objectives of the European Long-Term Space Plan with the best possible relationship between the requirements of cost and effectiveness, while optimising the use of European space resources available within the Agency and the Member States,

HAVING REGARD to Resolutions ESA/C-M/CIV/Res.1 (Final) on the implementation of the European Long-Term Space Plan and programmes and ESA/C-M/CIV/Res.3 (Final) on space cooperation with the Russian Federation, both adopted this day,

RECALLING the conclusions of the Report on the prospects for widening international space cooperation (ESA/C(92)74) from the Council Working Group on international cooperation set up on 12 December 1991,

HAVING REGARD to Articles II and XIV of the ESA Convention,

1. INVITES the Director General and the Member States to strengthen the coherence and coordination of their activities and programmes in the space field, and to make optimum use, in implementing these programmes, of existing resources and expertise within the Agency and the Member States.

2. INVITES the Director General to pursue his efforts to achieve synergy between the Agency's activities and those of the European Communities in areas where those activities complement each other, in particular in the area of observation of the Earth and its environment.

3. EXPRESSES THE WISH that the results of the Agency's programmes be put to the best possible use by other European space organisations such as Eutelsat and Eumetsat, under arrangements for making these available to be determined together with these organisations, in order in particular to avoid the duplication of research and development work.

4. INVITES the Director General to seek, together with those responsible for cooperation in the Member States concerned and with the appropriate international bodies, ways of making available to the developing countries, on mutually acceptable terms, appropriate data obtained through the Agency's programmes that can be of use to them, in accordance with the provisions of the Agency's Rules on information and data; and INVITES the Director General to prepare a report on the aforementioned cooperation with developing countries so as to enable Council to discuss the Agency's policy in that area.

5. EXPRESSES SATISFACTION at the extensive cooperation engaged in with Canada and Finland.

6. RECOGNISES that the execution of the Agency's programmes during the years ahead in line with the Director General's proposal on the Agency's policy and programmes (ESA/C-M(92)/3) will promote a deepening of the long-standing cooperation with the United States, will make it possible to carry out joint activities with Russia, and will allow the foundations to be laid for closer cooperation with Japan.

7. NOTES with interest the achievements of many countries, in particular those in central and eastern Europe, in areas of space research and development and EXPRESSES THE WISH that the Agency continue to maintain and develop relations with those countries.

Résolution sur la coopération internationale

adoptée le 10 novembre 1992

Le Conseil, siégeant au niveau ministériel,

RAPPELANT que la Résolution ESA/C-M/XCVII/Rés. 1 (Final) sur le plan spatial européen à long terme et les programmes adoptée à Munich le 20 novembre 1991 réaffirmait la nécessité d'intensifier la coopération internationale, tout en prenant en compte l'évolution du contexte géopolitique, en vue de réaliser pleinement les objectifs dudit plan à long terme avec le meilleur rapport possible entre les impératifs de coût et d'efficacité, tout en optimisant l'utilisation des ressources spatiales européennes disponibles au sein de l'Agence et dans les Etats membres,

VU les Résolutions ESA/C-M/CIV/Rés. 1 (Final) sur la mise en oeuvre du plan spatial européen à long terme et les programmes et ESA/C-M/CIV/Rés. 3 (Final) sur la coopération spatiale avec la Fédération de Russie adoptées ce jour,

RAPPELANT les conclusions du Rapport sur les perspectives d'un élargissement de la coopération internationale dans le domaine spatial (ESA/C(92)74) du Groupe de travail du Conseil sur la coopération internationale établi le 12 décembre 1991,

VU les articles II et XIV de la Convention de l'Agence,

1. INVITE le Directeur général et les Etats membres à renforcer la cohérence et la coordination de leurs activités et programmes dans le domaine spatial, ainsi qu'à faire un usage optimal, dans la mise en oeuvre de ces programmes, des moyens et compétences existant à l'Agence et dans les Etats membres.

2. INVITE le Directeur général à poursuivre ses efforts pour développer une synergie entre les activités respectives de l'Agence et des Communautés Européennes dans les domaines où ces activités sont complémentaires, en particulier dans le domaine de l'observation de la Terre et de son environnement.

3. SOUHAITE que les résultats des programmes de l'Agence soient utilisés au mieux par les autres organisations spatiales européennes telles Eutelsat et Eumetsat, selon des modalités de mise à disposition à définir avec ces organisations, pour éviter en particulier une duplication des efforts de recherche et développement.

4. INVITE le Directeur général à rechercher, de concert avec les responsables de la coopération des Etats membres intéressés et avec les organisations internationales compétentes, les voies permettant de mettre à la disposition des pays en développement dans des conditions mutuellement acceptables les données pertinentes obtenues au moyen des programmes de l'Agence qui pourraient leur être profitables, selon les dispositions du Réglement sur les informations et données de l'Agence; et INVITE le Directeur général à préparer un rapport sur la coopération avec les pays en développement visée ci-dessus afin de permettre au Conseil de discuter la politique de l'Agence dans ce domaine.

5. SE FELICITE de la coopération très large qui se poursuit avec le Canada et la Finlande.

6. RECONNAIT que l'exécution des programmes de l'Agence au cours des prochaines années conformément à la proposition du Directeur général sur la politique et les programmes de l'Agence (ESA/C-M(92)/3) favorisera l'approfondissement de la coopération établie de longue date avec les Etats-Unis, permettra de mener des activités en commun avec la Russie et de jeter les bases d'une coopération plus étroite avec le Japon.

7. NOTE avec intérêt les réalisations de nombreux pays, en particulier ceux situés en Europe centrale et orientale, dans les domaines de la recherche et du développement en matière spatiale et SOUHAITE que l'Agence continue d'entretenir et de développer des relations avec ces pays.

Resolution on Space Cooperation with the Russian Federation

adopted on 10 November 1992

The Council meeting at Ministerial Level,

WHEREAS ESA/C-M/XCVII/Res. 1 (Final) on the European Long-Term Space Plan and programmes, adopted in Munich on 20 November 1991, reaffirmed the need to intensify international cooperation with a view to achieving fully the objectives of the European Long-Term Space Plan with the best possible relationship between the requirements of cost and effectiveness, while optimising the use of European space resources available within the Agency and the Member States,

HAVING REGARD to ESA/C-M/CIV/Res.1 (Final) on the implementation of the European Long-Term Space Plan and programmes and ESA/C-M/CIV/Res.2 (Final) on international cooperation, both adopted this day,

TAKING NOTE of the diplomatic note dated 28 April 1992 by which the Russian Federation explicitly declared its wish to exercise the rights and fulfil the obligations stemming from the Agreement concerning cooperation in the field of the exploration and use of outer space for peaceful purposes, signed by the Agency and the Government of the Union of Soviet Socialist Republics on 25 April 1990,

WISHING to increase the existing cooperation between the Agency and Russia and extend it not only in all the areas already referred to in the aforementioned Agreement, but also in the areas of manned in-orbit infrastructure, crew transport and the associated communication facilities,

HAVING REGARD to the joint statement signed on 12 October 1992 by the Director General of the European Space Agency and the Director General of the Russian Space Agency (RKA),

HAVING REGARD to Article XIV.1 of the Convention,

I. EXPRESSES SATISFACTION at the results obtained so far in the framework of the cooperation activities undertaken in the fields of space science, space biology and medicine, microgravity research, Earth observation and crewed space transport systems; and WELCOMES the prospects for intensifying cooperation between the Agency and the Russian Federation.

II. ENDORSES the Director General's proposals, as described in his Proposal for the Agency's policy and programmes (ESA/C-M(92)3), to widen and strengthen such active cooperation with the space institutes of the Russian Federation during the period 1993–95, in the following main areas:

(a) in-orbit infrastructure
(b) crew transport facilities
(c) communication facilities associated with the in-orbit infrastructure
(d) missions onboard the Mir station, including the flight and accommodation of astronauts and payloads, to prepare the Agency for the use of inhabited space infrastructures.

III. AGREES that all the cooperation referred to in Section II above shall be reviewed by Council by the end of 1993, on the basis of reports by the Director General.

IV. INVITES the Director General to negotiate and submit to it as soon as possible the practical procedures for the cooperation activities identified in this Resolution for the period 1993–95, which shall be laid down in implementing arrangements within the meaning of Article 6 of the Agreement referred to above, and to be concluded between ESA and the Russian Space Agency (RKA), as well as in contracts with Russian industrial or research centres more specifically concerned with each of the cooperation themes selected, all the legal instruments concerned to be approved by the appropriate Agency bodies.

Résolution sur la coopération spatiale avec la Fédération de Russie

adoptée le 10 novembre 1992

Le Conseil, siégeant au niveau ministériel,

RAPPELANT que la Résolution ESA/C-M/XCVII/Rés. 1 (Final) sur le plan spatial européen à long terme et les programmes adoptée à Munich le 20 novembre 1991 réaffirmait la nécessité d'intensifier la coopération internationale en vue de réaliser pleinement les objectifs dudit plan à long terme avec le meilleur rapport possible entre les impératifs de coût et d'efficacité, tout en optimisant l'utilisation des ressources spatiales européennes disponibles au sein de l'Agence et dans les Etats membres,

VU les Résolutions ESA/C-M/CIV/Rés. 1 (Final) sur la mise en oeuvre du plan spatial européen à long terme et les programmes et ESA/C-M/CIV/Rés. 2 (Final) sur la coopération internationale adoptées ce jour,

PRENANT ACTE de la note diplomatique du 28 avril 1992 par laquelle la Fédération de Russie a expressément déclaré sa volonté d'exercer les droits et de respecter les obligations qui découlent de l'Accord entre l'Agence spatiale européenne et le Gouvernement de l'Union des républiques socialistes soviétiques relatif à la coopération dans le domaine de l'exploration et de l'utilisation de l'espace extra-atmosphérique à des fins pacifiques signé le 25 avril 1990,

DESIREUX d'amplifier la coopération existante entre l'Agence et la Russie et de l'étendre non seulement dans tous les domaines déjà visés dans l'Accord mentionné ci-dessus mais aussi dans les domaines de l'infrastructure habitée en orbite, des transports d'équipages et des moyens de communication associés,

VU la Déclaration commune signée le 12 octobre 1992 par le Directeur général de l'Agence spatiale européenne et par le Directeur général de l'Agence spatiale russe (RKA),

VU l'article XIV.1 de la Convention,

I. EXPRIME SA SATISFACTION devant les résultats obtenus à ce jour dans le cadre de la coopération entreprise dans les domaines de la science spatiale, de la biologie et de la médecine spatiales, de la recherche en microgravité, de l'observation de la Terre et des systèmes de transport spatial habité, et ACCUEILLE FAVORABLEMENT les perspectives d'intensification de cette coopération entre l'Agence et la Fédération de Russie.

II. FAIT SIENNES les propositions du Directeur général, telles que décrites dans sa Proposition sur la politique et les programmes de l'Agence (ESA/C-M(92)3), d'élargir et de renforcer cette coopération avec les institutions spatiales de la Fédération de Russie, au cours de la période 1993–1995, dans les principaux domaines suivants:
(a) infrastructure en orbite
(b) moyens de transport des équipages
(c) moyens de communication associés à l'infrastructure en orbite
(d) missions à bord de la station Mir, y compris l'emport et le séjour d'astronautes et de charges utiles, afin de préparer l'Agence à l'utilisation des infrastructures spatiales habitées.

III. CONVIENT que l'ensemble de la coopération décrite au paragraphe II ci-dessus fera l'objet d'un examen par le Conseil avant la fin de 1993, sur la base de rapports du Directeur général.

IV. INVITE le Directeur général à négocier et à lui soumettre au plus tôt les modalités concrètes des coopérations identifiées dans la présente Résolution pour la période 1993–1995, modalités qui devront être reprises dans des arrangements de mise en oeuvre au sens de l'article 6 de l'Accord de coopération susvisé à conclure entre l'Agence et l'Agence spatiale russe (RKA), ainsi que dans des contrats avec les centres industriels ou de recherche russes portant plus spécifiquement sur chacun des thèmes de coopération retenus, tous instruments juridiques devant être agréés par les organes compétents de l'Agence.

V. STRESSES that space cooperation of this kind between the Agency and the Russian Federation must safeguard the interests of the space industry of the Member States, including in the launch services sector.

VI. INVITES the Director General to make sure that such cooperation over the period 1993–95 proceeds in accordance with the objectives of the European Long-Term Space Plan, to report periodically on progress made in the corresponding work, and to propose any changes or reorientation which he may consider necessary.

VII. AGREES to undertake, in due course, a review of the main results of the cooperation activities conducted pursuant to Section II, so that the complementary decisions referred to in Chapters II and VII of ESA/C-M/CIV/Res.1 (Final), adopted this day, can be taken by the end of 1995, and INVITES the Director General to take the measures needed to make it possible for cooperation between the Agency and the Russian Federation to continue beyond 1995, if so desired, under the terms of a new Agreement.

V. RAPPELLE que la conduite d'une telle coopération spatiale entre l'Agence et la Fédération de Russie doit sauvegarder les intérêts de l'industrie spatiale des Etats membres, y compris dans le secteur des services de lancement.

VI. INVITE le Directeur général à s'assurer que le déroulement de cette coopération sur la période 1993-1995 s'effectue en conformité des objectifs du plan spatial européen à long terme, à faire périodiquement rapport sur l'avancement des travaux correspondants, et à proposer les modifications ou réorientations qu'il juge nécessaires.

VII. CONVIENT de procéder, en temps utile, à un examen des principaux résultats des coopérations engagées au titre du paragraphe II ci-dessus en vue de permettre la prise avant la fin de 1995 des décisions complémentaires visées aux chapitres II et VII de la Résolution ESA/C-M/CIV/Rés. 1 (Final) adoptée ce jour, et INVITE le Directeur général à prendre les mesures nécessaires permettant l'éventuelle poursuite de la coopération entre l'Agence et la Fédération de Russie au-delà de 1995 selon les termes d'un nouvel Accord.

ESA/C(92)96, Add. 1

Final Declaration of the ESA Council Meeting at Ministerial Level

1. The Council of the European Space Agency, meeting at Ministerial Level in Granada on 9 and 10 November 1992 under the Chairmanship of Prof. Hubert Curien, French Minister of Research and Space, considered the proposals put forward by the Director General for the Agency's policy and programmes, as requested by the Ministers at their previous meeting held in Munich in November 1991.

2. This Meeting was attended by Ministers representing the thirteen Member States of the Agency, and by Ministers from Finland (Associate Member) and Canada (Cooperating State). In addition, the Commission of the European Communities, Eutelsat and Eumetsat were granted observer status.

3. The Director General's proposals were welcomed and endorsed by the Ministers as a strategic framework for the Agency's activities, planning and programmes, constituting a satisfactory response to the need to achieve the best possible relationship between the requirements of cost and effectiveness, in particular through widened and strengthened international cooperation.

4. The Council adopted three Resolutions: Resolution No.1 on the implementation of the European long-term space plan and programmes, Resolution No. 2 on international cooperation, and Resolution No. 3 on space cooperation with the Russian Federation.

4.1. In Resolution No.1, the Ministers approved: (i) Envisat-1, the first in a series of missions designed to tackle the problems of Earth's environment and to ensure continuity with the data provided by the Agency's ERS-1 and ERS-2 satellites; and (ii) preparatory activities for the first meteorological and climate monitoring mission, Metop-1, which is planned for launch in 2000 and will be developed in cooperation with Eumetsat. The Ministers also recognised the need to start up a programme in 1993 for a second-generation Meteosat system, to be developed in close collaboration with Eumetsat for a first launch in 1999, and also invite the Director General to submit in 1993 a programme proposal concerning an Earth observation data user programme.

The Ministers further welcomed the work carried out to date by the Committee on Earth Observation Satellites (CEOS) towards developing a world-wide environmental monitoring network and the proposal for a Space Agency Forum to carry on the work of SAFISY in International Space Year, as well as the activities of the Inter-Agency Consultative Working Group, towards coordination in space science, recognising that they could in time contribute to the evolution of a World Space Agency.

4.2. In the field of telecommunications, the Ministers confirmed the continuation of the Data Relay and Technology Mission (DRTM) programme, to include the full development and launch in 1999 of DRS-1, designed to ensure transmission of data from Envisat-1 and Metop-1 and forming an element essential for the operation of manned space vehicles.

4.3. With regard to programmes aimed at allowing European human activities in space:
– The Ministers confirmed the continuation of the Columbus development programme, in four elements: the development and launch in 1999 of the Columbus Attached Laboratory (APM); the development and launch in 1998 of the Columbus Polar Platform; precursor flight activities to prepare European astronauts and user communities for the exploitation of the International Space Station; and system studies and definition activities for a future space station, to be carried out in international cooperation.
– The Ministers also agreed on a three-year re-orientation phase, running from 1 January 1993, for the Hermes programme, in order to study three strategic options for implementing a future crewed space transportation system. These options will be studied in cooperation with Russia and with the United States.

Déclaration finale du Conseil de l'ESA siégeant au niveau ministériel

1. Le Conseil de l'Agence spatiale européenne siégeant au niveau ministériel à Grenade les 9 et 10 novembre 1992 sous la présidence de M. Curien, Ministre de la Recherche et de l'Espace de la France, a examiné les propositions soumises par le Directeur général en ce qui concerne la politique et les programmes de l'Agence comme le lui avaient demandé les Ministres lors de leur précédente session qui s'était déroulée à Munich en novembre 1991.

2. La présente session a réuni les Ministres représentant les treize Etats membres de l'Agence ainsi que les Ministres de la Finlande (membre associé) et du Canada (Etat coopérant). La Commission des Communautés européennes, Eutelsat et Eumetsat y ont en outre assisté en qualité d'observateurs.

3. Les propositions du Directeur général ont été accueillies favorablement par les Ministres qui les ont entérinées en tant que cadre stratégique des activités, plans et programmes de l'Agence répondant de façon satisfaisante à la nécessité de parvenir au meilleur rapport possible entre les impératifs de coût et d'efficacité, en particulier grâce à un élargissement et à un renforcement de la coopération internationale.

4. Le Conseil a adopté trois Résolutions: la Résolution no. 1 a trait à la mise en oeuvre du plan spatial européen à long terme et des programmes, la Résolution no. 2 porte sur la coopération internationale et la Résolution no. 3 traite de la coopération spatiale avec la Russie.

4.1. Par la Résolution no. 1, les Ministres ont approuvé: (i) Envisat-1, la première d'une série de missions ayant pour objectifs de faire face aux problèmes touchant à l'environnement et de garantir la continuité des données fournies à l'Agence par les satellites ERS-1 et ERS-2; et (ii) des activités de préparation d'une première mission de météorologie et de surveillance du climat, Metop-1, devant être lancée en l'an 2000, qui sera réalisée en coopération avec Eumetsat. Les Ministres ont également reconnu qu'il fallait engager en 1993 un programme portant sur un système Météosat de deuxième génération, qui doit être réalisé en étroite collaboration avec Eumetsat et dont le premier exemplaire sera lancé en 1999. Ils ont en outre invité le Directeur général à soumettre en 1993 une proposition relative à un programme pour les utilisateurs de données d'observation de la Terre.

Les Ministres ont également fait bon accueil aux travaux conduits jusqu'ici par le Comité sur les satellites d'observation de la Terre (CEOS) en vue de mettre sur pied un réseau mondial de surveillance de l'environnement, et à la proposition d'organiser un Forum des Agences spatiales qui permettrait de poursuivre les travaux réalisés dans le cadre du SAFISY pendant l'Année internationale de l'Espace, ainsi qu'aux activités du Groupe de travail consultatif inter-agence pour une meilleure coordination dans le domaine des sciences spatiales, reconnaissant qu'ils pourraient apporter une contribution à l'évolution d'une Agence spatiale mondiale.

4.2. Dans le domaine des télécommunications, les Ministres ont confirmé la poursuite du programme de mission de technologie et de relais de données (DRTM) qui doit couvrir la réalisation proprement dite du DRS-1 et son lancement en 1999 en vue d'assurer la transmission des données d'Envisat-1 et de Metop-1; le programme DRTM constitue un élément capital pour l'exploitation de véhicules spatiaux avec équipage.

4.3. En ce qui concerne les programmes devant permettre à l'Europe de participer à la présence de l'homme dans l'espace,

– les Ministres ont confirmé la poursuite du programme de développement Columbus en quatre éléments: la réalisation et le lancement en 1999 du laboratoire raccordé Columbus (APM), la réalisation et le lancement en 1998 de la plate-forme polaire Columbus, l'exécution de vols précurseurs pour préparer les astronautes européens et les communautés d'utilisateurs à l'exploitation de la Station spatiale internationale et enfin des activités de définition et d'étude système portant sur une future station spatiale à conduire dans le cadre d'une coopération internationale.

– pour ce qui est du programme Hermès, les Ministres sont également convenus d'une phase de réorientation de trois ans, à compter du 1er janvier 1993, afin d'étudier trois options stratégiques pour la mise en oeuvre d'un futur système de transport spatial avec équipage. Ces options seront étudiées en coopération avec la Russie et avec les Etats-Unis.

5. The Ministers invited the Director General to present a report on the overall situation of the in-orbit infrastructure programmes mentioned above, in time for a review of these programmes which is to take place in February 1995 as preparation for the taking of complementary decisions on each of the programmes concerned.

6. With regard to the other activities carried on by the Agency, the Ministers confirmed the Director General's proposals in such fields as science, Earth observation, microgravity, telecommunications and Ariane launcher programmes.

7. Specific attention was also given to the necessary continuation of activities at the Guiana Space Centre, as an essential element in the Agency's strategy. Further, the Ministers reaffirmed the strategic character of the Ariane launcher, which ensures Europe's autonomous access to space, and invited the Director General to work out, in cooperation with the European Communities and the Member States, the terms of fair conditions of competition in the world launch-services market.

8. The Ministers reviewed the industrial return achieved thus far both at the overall level and under each programme; they decided to fix at 0.96 the lower limit for overall cumulative return for the period 1994–1996; they invited the Director general to formulate measures to further improve the management of the Agency's programmes and to propose measures to achieve an equitable financial system with regard to exchange-rate fluctuations.

9. The Ministers announced the level of contributions applicable to the participation of their respective States in the continuation of the DRS programme element and of the POEM-1, Columbus and Hermes programmes, some of them linking their confirmation to the settlement of an outstanding financial point.

10. In Resolution No. 2, on international cooperation, the Ministers reaffirmed the need to strengthen the coherence between the Agency's and Member States' programmes, and recognised the importance of achieving greater synergy between the efforts of the Agency and those of the Commission of the European Communities in using and exploiting the Agency's products, while preserving their respective roles, and between the Agency and other European space organisations such as Eutelsat and Eumetsat.

    The Ministers also called for a deepening and widening of the Agency's relationships with its international partners, in particular the United States, Russia and Japan, in order to use the existing space capabilities to each other's benefit.

11. In Resolution No. 3, the Ministers endorsed the Director General's proposal to widen and strengthen space cooperation with Russia during the period 1993–1995. This cooperation includes joint studies in the areas of in-orbit infrastructure and associated communications, crewed transportation systems, and missions by European astronauts to the Mir station.

    The Ministers agreed to consider, in February 1995, proposals on the scope and content of the next step of the European space plan.

12. To conclude, the Ministers expressed considerable satisfaction at the very positive results achieved on the occasion of this Council Meeting, and their gratitude to the Government of Spain for its hospitality and to the city of Granada for the excellent atmosphere it contributed to create. They are convinced that this Meeting will contribute significantly to reinforcing the cohesion of European space policy.

5. Les Ministres ont invité le Directeur général à présenter un rapport sur la situation d'ensemble des programmes d'infrastructure orbitale mentionnés ci-dessus, lequel rapport sera remis en temps voulu pour l'examen de ces programmes qui doit avoir lieu en février 1995 en préparation des décisions complémentaires à prendre pour chacun d'eux.

6. En ce qui concerne les autres activités en cours à l'Agence, les Ministres ont confirmé les propositions faites par le Directeur général dans des domaines tels que le programme scientifique, l'observation de la Terre, la microgravité, les télécommunications et les programmes de lanceurs Ariane.

7. L'accent a également été mis sur la nécessité de poursuivre les activités menées au Centre spatial guyanais, qui est un élément essentiel de la stratégie de l'Agence. Les Ministres ont en outre réaffirmé le caractère stratégique du lanceur Ariane, qui garantit à l'Europe un accès autonome à l'espace, et ont invité le Directeur général à définir, en coopération avec les Communautés européennes et les Etats membres, les conditions d'une concurrence équitable sur le marché mondial des services de lancement.

8. Les Ministres ont examiné le retour industriel obtenu jusqu'ici tant au niveau global que dans chacun des programmes; ils ont décidé de fixer à 0,96 la limite inférieure du coefficient de retour global cumulé pour la période 1994–1996. Ils ont invité le Directeur général à définir des mesures visant à améliorer la gestion des programmes de l'Agence et à proposer d'autres mesures devant aboutir à un mécanisme financier équitable qui prenne mieux en compte les fluctuations des taux de change.

9. Les Ministres ont annoncé le niveau des contributions correspondant à la participation de leurs Etats respectifs à la poursuite de l'élément de programme DRS et des programmes POEM-1, Columbus et Hermès, certains liant leur confirmation au règlement d'un élément financier.

10. Aux termes de la Résolution no. 2 relative à la coopération internationale, les Ministres ont raffirmé la nécessité de renforcer la cohérence entre les programmes de l'Agence et ceux des Etats membres. Ils ont également reconnu qu'il était important de développer la synergie entre les activités de l'Agence et de la Commission des Communautés européennes pour utiliser et exploiter les résultats de l'Agence tout en respectant le rôle qui revient à chacune d'elles, ainsi qu'entre les efforts déployés par l'Agence et d'autres organisations spatiales européennes comme Eutelsat et Eumetsat.

Les Ministres ont également demandé à l'Agence d'approfondir et de développer ses relations avec ses partenaires internationaux, en particulier les Etats-Unis, la Russie et le Japon, afin d'utiliser les capacités spatiales existantes au bénéfice de chacun.

11. Aux termes de la Résolution no. 3, les Ministres ont entériné la proposition du Directeur général visant à élargir et renforcer la coopération spatiale avec la Russie au cours de la période 1993–1995. Cette coopération porte notamment sur des études communes dans les domaines de l'infrastructure orbitale et des télécommunications associées et en ce qui concerne les moyens de transport avec équipage et les missions d'astronautes européens à bord de la station Mir.

Les Ministres sont convenus d'examiner en février 1995 des propositions relatives à la portée et au contenu de la prochaine étape du Plan spatial européen.

12. Pour conclure, les Ministres se sont déclarés très satisfaits des résultats très positifs de la présente session au niveau ministériel et ont remercié le gouvernement espagnol pour son hospitalité ainsi que la ville de Grenade pour l'excellente atmosphère qu'elle a contribué à créer. Ils sont convaincus que cette réunion contribuera de manière significative à renforcer la cohésion de la politique spatiale européenne.

Ulysses Operations at Jupiter – Planning for the Unknown

N. Angold, P. Beech, R. Garcia-Perez, A. McGarry* & S. Standley*
Mission Operations Department, European Space Operations Centre (ESOC), Darmstadt, Germany
Currently at Jet Propulsion Laboratory, Pasadena, California

Ulysses was launched in October 1990 and, following its successful deployment from the Space Shuttle 'Discovery', was targetted on its journey to Jupiter using an upper-stage combination consisting of an Inertial Upper Stage and a PAM-S booster. Trajectory corrections were made using on-board thrusters, twice in October 1990 and finally in July 1991. No further corrections were required after this date because sufficient accuracy had been obtained to achieve the mission design target for the Jupiter encounter range.

This article describes the operational preparations necessary for the encounter with Jupiter, and the activities that took place when the flyby occurred in early February 1992. The scientific results from this phase of the Ulysses mission are discussed in the companion article on pages 52—59 of this Bulletin.

Introduction

Following extensive studies in the mid-1970s at both ESA and NASA to investigate a feasible concept for achieving an out-of-ecliptic mission, it became clear that the only viable approach was to exploit the gravitational field of Jupiter in a so-called 'swingby', which would cause the spacecraft orbit to be deflected away from the ecliptic plane in either a northerly or southerly direction.

The project's early history reflected many changes. Finally, in 1981 the mission was defined as a single spacecraft provided by ESA with a power source provided by NASA and a payload consisting of both European and American experiments. The launch capability, using the Space Shuttle, and ground facilities, using the Deep-Space Network (DSN) in association with a Control Centre at the Jet Propulsion Laboratory in Pasadena, California, were to be provided by NASA. Hardware and software to control the spacecraft in orbit were to be provided by ESA and were integrated at JPL initially in 1985, and then following the 'Challenger' accident, again in 1990. The spacecraft mission was to be carried out by a joint ESA/NASA team.

The decision was taken in 1985 to target the trajectory for a south-going polar passage, which would be followed approximately one year later by a north-going passage. Initial operational discussions centred around maintaining the spacecraft in a safe configuration during its hazardous approach to Jupiter, and little concrete planning was done to derive scientific benefit from the flyby.

However, the encounter also provided a unique opportunity to make scientific measurements to complement those made by the previous spacecraft visitors to Jupiter. As planning progressed and the scientific investigators decided on the best configurations for their instruments, it became clear that operations during this period of the mission would be extremely complex. A single timeline that incorporated all spacecraft and ground-segment activities would be required in order to ensure a safe passage past the planet and to maximise the scientific return.

Planning for survival in the Jovian environment

Previous Jovian odysseys: lessons learned

Four spacecraft had crossed the Jovian magnetosphere before Ulysses: Pioneers-10 and 11 in 1973 and 1974, and Voyagers-1 and 2 in 1979. Each of them experienced anomalies associated with the harsh Jovian environment. These included:
- spurious command execution
- spontaneous changes of spacecraft state
- permanent instrument degradation
- detector saturation
- data outages caused by on-board computer stopping
- spacecraft timing corruption caused by spacecraft internal clock halting
- radiation damage to crystal oscillator producing frequency shifts.

* Vega Group PLC

Each of these anomalies can be associated with one or more of the following causes:
- high radiation flux levels
- electrostatic surface discharges
- internal discharges
- single-event upsets, i.e. direct radiation impacts on the microelectronics.

Protection against such effects was therefore a strong requirement during the Ulysses spacecraft's design and development. Even so, the Operations Team felt it prudent to 'expect the unexpected', and a number of contingencies were planned for. The main areas of concern were:
- unexpected activation of the spacecraft power subsystem protection logic which switches off all the scientific instruments; the recovery procedures were designed to minimise science data loss whilst still ensuring that the safety of the spacecraft was maintained
- unexpected activation of any other automatic on-board protection functions
- saturation of, or permanent damage to, sensitive instruments
- spacecraft clock resets
- alteration of analogue parameters (e.g. currents, voltages, gains).

In addition, the experiment teams produced strategies to protect their instruments and these were integrated into the timeline.

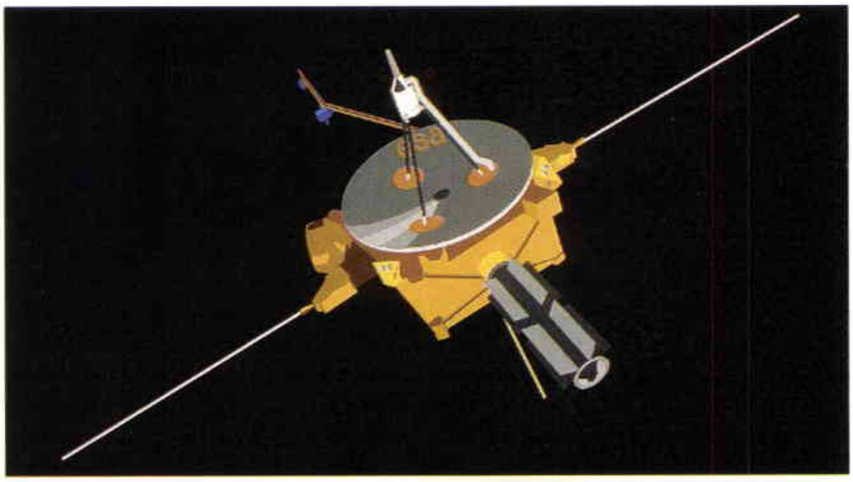
Trajectory implications

A key requirement was to minimise the radiation dose absorbed by the spacecraft during flyby. Using models for the trapped radiation environment based on measurements made by the four previous probes, constraints were placed on the trajectory design:
- the minimum Jupiter flyby distance should be greater than 6.3 Jovian radii (450 000 km) from the centre of the planet
- since Jupiter's 10 h rotation period modulates the radiation levels in the equatorial regions near the planet, the magnetic-equator crossing would be timed to coincide with a minimum in the radiation fluence.

Integrated platform and payload operations timeline

The instruments on Ulysses were designed to make observations in the solar wind under the relatively slowly changing conditions encountered in the interplanetary medium. As a consequence, payload operations during the routine phases of the mission have generally been limited to periodic instrument calibration sequences and occasional reconfigurations or mode changes. The ability to make measurements in Jupiter's magnetosphere was not a primary driver for the design of the majority of the instruments, and so the problem of optimisation of Jovian observations had, in most cases, to be solved operationally. Once inside the magnetosphere, with its rapidly changing environment, far more payload commanding became necessary.

Instrument reconfigurations are normally 'time-tagged', i.e. the command is loaded into the time-tag buffer of the Data Handling Subsystem (DHS), which then releases the command to the instrument at the specified time. Since the Ulysses DHS can only hold 40 time-tagged commands, and with the level of payload activity planned, it was impossible to tag them all.

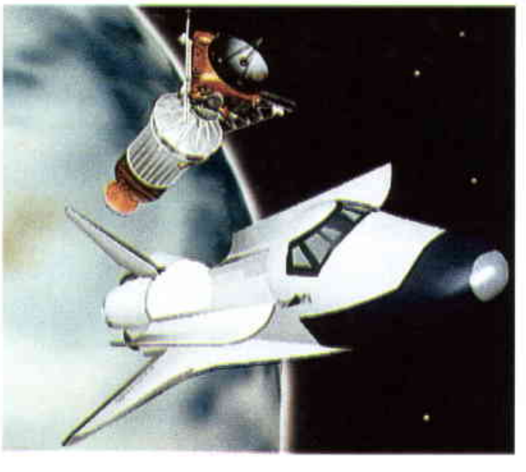


Starting a year before Jupiter encounter, experiment teams' flyby requirements were collected. The initial responses highlighted several potential problem areas:
- commanding rate: this was so high that instruments' commanding times conflicted
- timing of command execution: this was more precise than expected, in some cases to within 5 s
- the environment: because of the unpredictability of the environment, many investigators were reluctant to define their commanding requirements in advance; they needed to command in near real-time based on their observations.

In addition to this, there were a number of limitations on the spacecraft platform operations:
- available spacecraft power was less than predicted, so each proposed platform/payload configuration would have to be checked for power shortfall before implementation

- minimal dynamic disturbance to the platform was requested, so as not to interfere with radio-science observations
- scheduling of additional DSN tracking passes for such times of high activity can be a time-consuming process and the DSN schedule is a fundamental driver of any Ulysses operation.

Given all of the above constraints, it was decided that the Flight Operations Plan would contain a timeline integrating all of the science, platform, and critical ground activities, to avoid inconsistencies and conflicts between the various requirements. The spacecraft power was a particularly difficult issue, as switching on the additional 35 W load of the S-band transponder to support the Radio Science team's observations of the Io Plasma Torus, would bring the spacecraft very close to its operational power limit. This led to the question of whether or not instruments should be turned off when S-band was on in order to provide power, or indeed if S-band should be used at all if it impacted other science observations. For this reason, the spacecraft's power budget and thermal balance were the dominant engineering concerns during planning and operations.



A timeline of science command and monitoring requirements was produced for the period between 1 January and 31 March 1992, giving the Flight Control Team a view of the timing and duration of peak activity levels. This first draft was used to predict manning levels, define the necessary shift plans, and request the correct DSN coverage for the encounter period. For each science investigation team, the Principal Investigator appointed an individual point of contact for the encounter planning. When conflicts arose between science activities, the Spacecraft Operations Team could then contact the representatives involved and resolve the conflicts quickly.

Prompt publication of a draft timeline was extremely important, as in such an eventful timeline single changes could have significant consequences in other areas. Without wishing to constrain the science investigations at an early stage, it was important that the development of each instrument team's ideas and activity schedules at least converged after the first draft was issued. Resolving a minor conflict in instrument commanding between two Ulysses science teams was usually easy, but attempting to reschedule a manoeuvre or extend a DSN pass was difficult, time-consuming, and sometimes generated further conflicts. In a process that was necessarily iterative, successive drafts were useful in establishing fixed points that the scientists and operations staff could refer to.

Instrument activities were interleaved with these essential engineering operations, minor adjustments to timing being made where necessary. As the Jupiter encounter timeline took shape, it became evident that there would be a power shortfall if careful attention was not paid to the power budget during the month of the flyby; the integrated timeline became a useful tool for calculating power requirements for each step of the encounter.

Power and thermal planning

Since Ulysses is a deep-space mission, travelling up to 5.4 AU (808 million km) from the Sun, the spacecraft's power requirements are met by the use of a nuclear power source, the Radioisotope Thermoelectric Generator (RTG). The Ulysses RTG, which provided 283 W at the beginning of the mission, converts the heat produced by radioactive decay into electricity by warming the hot junctions of thermocouple sets. Because of the radioactive nature of the source, the power output from the RTG decays over a period of years. In Ulysses' case, RTG output had already diminished during the storage period following the 1986 launch delay.

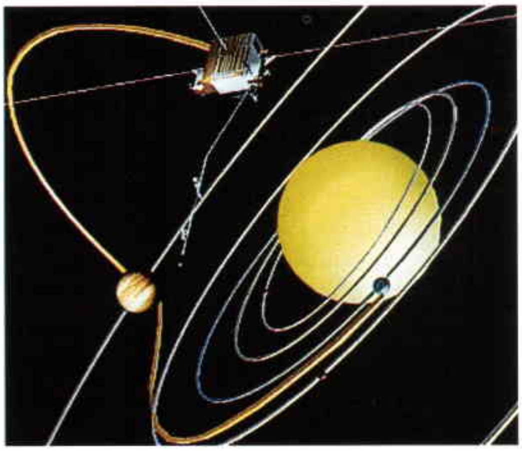
Because the RTG, over short mission phases, can be considered to provide a constant amount of power, excess power must be dumped to sets of resistances. This excess power is used to control the spacecraft's thermal balance by selecting the proportion to be dumped via external or internal power dumpers. Since at Jupiter encounter the spacecraft was approaching the coldest part of the mission, all power was dumped internally to assist in platform heating.

When a unit is switched on, the necessary power is taken from the internal power dumpers. If they contain insufficient power to meet this demand, the spacecraft protection logic maintains the main bus voltage by disconnecting non-essential loads. Unfortunately, in such a case the payload is considered non-essential, and is switched off. Since recovery can take from 12 to 24 h, there was a risk of losing a significant part of the Jovian science in the event of a power shortfall during the flyby.

The spacecraft required additional power during the flyby because:
- its S-band transmitter was operating in addition to the nominal X-band downlink, resulting in an extra 35 W load
- the instruments were predicted to draw more power in the intense radiation environment around Jupiter (it was not known exactly what they would require, but the figure was no more than an additional 5 W above nominal payload power)
- cover closure was required for the HI-SCALE instrument (see Table 1) during the flyby, an operation that required an additional 2 W
- the SWICS instrument was colder than predicted for this phase of the mission, and exhibited undesirable characteristics when at low temperatures and so extra heating was required, involving an additional 2 W
- some instruments were switched off during the flyby to protect them from radiation damage, but used more power when off than on because of compensation-heater operation
- autonomous switchover to redundant units had to be considered, and some redundant units use more power than the prime.

Rigorous power planning was made difficult because:
- available spacecraft power could not be measured, but had to be calculated using an algorithm accurate to within only 3 to 4 W
- extrapolating the decay curve of the RTG with only 1 year of flight data was thought to be unreliable (although the prediction of 263 W at Jupiter encounter turned out to be very good in retrospect)
- internal power-dumper capacity can be monitored in telemetry at a rate of one sample every 32 s, and a variation of 5 W is observed.

Because of all of the above, the following rules were adopted during encounter planning:
- RTG power predictions; the encounter was planned using RTG power predictions, and then modified as the time of encounter approached and the power available was visible in telemetry
- a 5 W operational power margin was established. If at any time the available power fell below this margin, the spacecraft would be commanded to a predetermined, proceduralised power-saving configuration
- a 3 W margin was established to allow for autonomous unit switching.



Meeting these criteria had a major influence on the mission. While the S-band transmitter was on, no manoeuvres were possible and the spacecraft tape recorders had to be off, and so round-the-clock DSN coverage was required for the encounter period.

Ground-segment planning

Facilities at JPL

The Ulysses Mission-Support Area (MSA) was totally reconfigured for the encounter to provide one area for the the Operations Team and another for the Science Teams. The Spacecraft Control and Monitoring System (SCMS) was run on both the real-time and back-up computers and the number of terminals increased to the maximum allowed for each machine. In this way, the experimenters gained access to real-time data via one computer whilst spacecraft control was being performed using the other, thereby eliminating competition for resources. In the event of a computer failure, the spacecraft control function would have taken priority and, if necessary, would have been switched immediately to the working machine, thus providing 'hot redundancy' for this critical task. In addition, a large display was installed to project a dynamic simulation of the spacecraft's trajectory within the Jovian system.

A Science Support Area was conveniently located in a building adjacent to the MSA, providing office space for 125 experimenters and interfaces for their computer equipment. Distribution of Ulysses experiment data to the science community during flyby was, as usual, via the JPL Data Record System (DRS) and the Data Management Team (DMT) undertook planned to produce Quick-look Experiment Data Records (QEDR) every hour during flyby. Experimenters could thereby access their data in near-real-time for processing either using support equipment located in the Science Support Area or back at their home institutes.

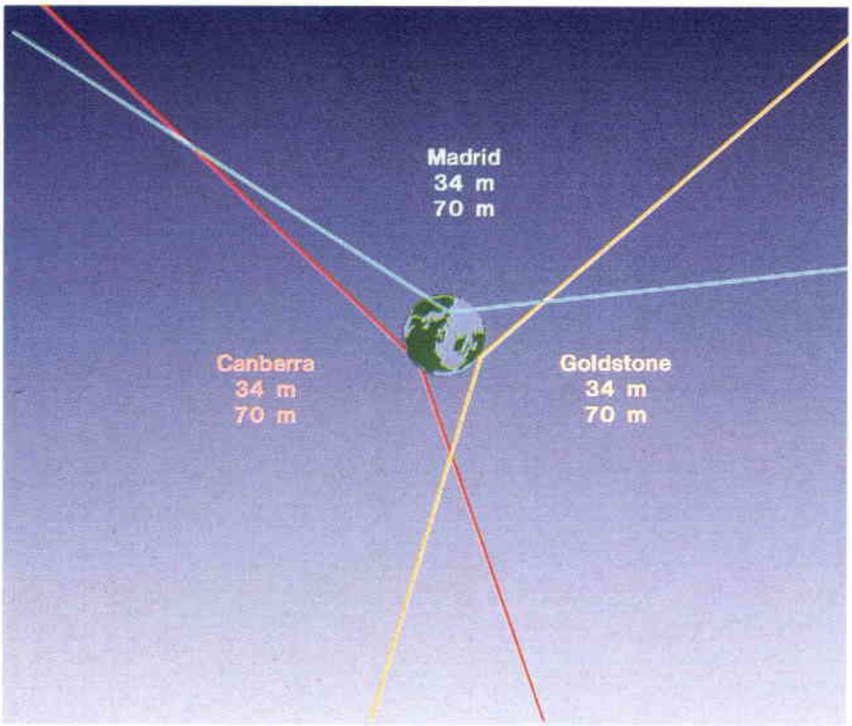


Figure 1. The Deep-Space Network (DSN) coverage.

Continuous support for hardware and software maintenance and QEDR production was provided during the encounter period.

Encounter simulation

Three months before flyby, the entire Mission Operations Team and many of the Science Teams took part in a simulation which followed the timeline of a day in the encounter period. The main purpose was to exercise the human interfaces and to assess ground-segment performance under conditions similar to those during flyby. Hardware failures were induced to test contingency planning and several key events, such as a bow-shock crossing, were also introduced by means of written input to the participants, who were then encouraged to act as they would during the real encounter.

The simulation proved most valuable since it highlighted several procedural and system problems. As a result, improvements were made to both the timeline and the ground segment, which resulted in smoother operations at the time of the encounter.

Deep-Space Network (DSN)

Continuous 24 h DSN coverage (Fig. 1) was scheduled to commence nine days before the Jupiter closest approach and to continue for more than a month, providing support also for the Gravitational Wave Experiment during the solar opposition period, which occurred immediately after the Jupiter encounter. Continuous coverage via the 70 m antennas was planned for the 36 h period on either side of closest approach using all three DSN sites – Madrid (Spain), Goldstone (USA) and Canberra (Australia). Back-up 34 m ground stations were also requested to provide double coverage when possible, thereby ensuring command capability in the event of a failure in one of the 70 m antennas.

Since the DSN antennas are used by many other projects, the schedule requests had to be negotiated and conflicts resolved many months in advance. This task was successfully accomplished by the JPL ground-segment management team and could not have been achieved without the cooperation of the other projects involved.

Encounter activities

Spacecraft operations during the Jupiter encounter

Although command activity during the encounter period followed the pre-defined operations timeline, the experiment teams were also able to submit real-time command requests to the Spacecraft Operations Team. The need for such requests arose from the fact that some instruments required reconfiguration, depending on where the spacecraft was with respect to the Jovian magnetosphere. This could not be predicted in advance because of the dynamic nature of the magnetosphere's interaction with the solar wind.

Moreover, because Ulysses' trajectory was different from those followed by previous visitors to Jupiter, the scientists were anxious to reconfigure their instruments in real-time to maximise the science return from this previously unexplored region. The fact that many of the instrument designs were not optimised for making measurements of the Jovian environment increased the number of commands required for this task.

During the 20 d period around closest approach, continuous uplink and downlink coverage via the Deep-Space Network provided full control and monitoring capabilities. At the same time, 24 h support was provided by both the JPL Data Management Team to ensure that the experiment teams received data via the QEDRs, and the Spacecraft Operations Team for preparing and checking real-time command sequences, their integration into the timeline, and transmission to the spacecraft.

The real-time command capability was utilised by all of the experiment teams and command requests ranged from the simple to the extremely complex. For a simple request, such as a single command to be transmitted only once, the typical time between receipt of a request and transmission was 10 to 30 min (the transmission time to the spacecraft, or one-way light time, was approximately 37 min). On the other hand, some command requests amounted to a complete change in daily commanding schedules, resulting in extensive changes to the existing timeline.

The resulting high level of command activity is reflected in the fact that 17% of the commanding for the first 500 days of the mission (from launch until 18 February 1992) was performed during the 8 days from 3 to 10 February (Fig. 2).

The experiments that make up the Ulysses spacecraft's payload are listed in Table 1 and the key encounter events are summarised in Table 2.

Spacecraft performance

Instrument calibration and science observations linked to the Jupiter encounter began in early December 1991, increasing in intensity up to the flyby. Successful engineering tests of power-saving modes that may have been necessary in the event of power shortfalls were also conducted. These tests involved briefly switching off combinations of instruments in order to confirm that the thermal transient on cooling would not violate lower temperature limits.

The last spacecraft slew manoeuvre before the encounter was perfectly nominal. Immediately after correct termination was verified, the S-band transponder was turned on and the wing heaters turned off, placing the spacecraft in the first of its power-constrained configurations. Achieving this configuration gave the Operations Team their first opportunity to check the validity of the power predictions that had been made during the planning stages; available power was in fact slightly higher than predicted.

The large thermal transients caused by the S-band switch-on were monitored with interest. The thruster-block temperatures stabilised 1° above their lower limits, exactly

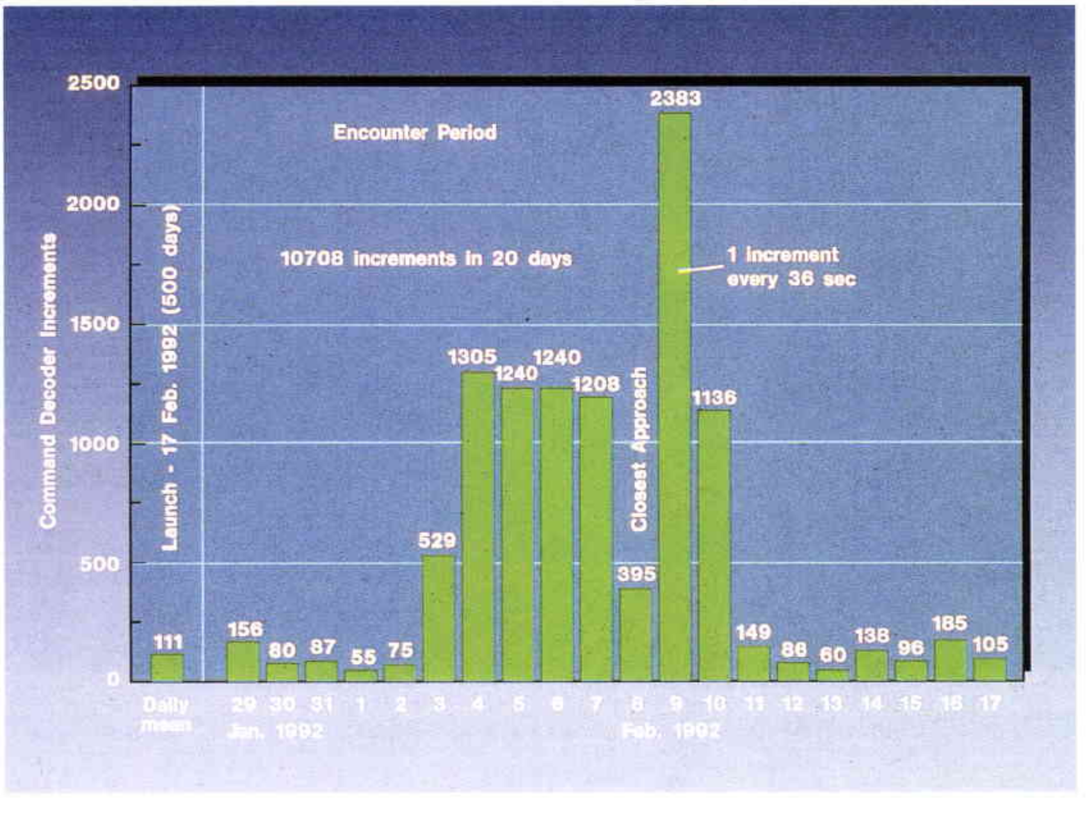


Figure 2. Ulysses command activity.

as predicted. Of more concern was the condition of the Solar-Wind Ion Composition Experiment (SWICS), which exhibits data degradation at low temperatures. Some data degradation was observed due to the S-band switch on.

No anomaly occurred until 12 h before closest approach, when the EPAC experiment showed a high detector current. The Contingency Recovery Procedure to switch the instrument off was implemented immediately. The EPAC team later confirmed that the anomalously high current was due to the high background, and because the instrument had been switched off it had sustained no damage.

No further problem occurred until after closest approach, when the COSPIN KET instrument had a current parameter go out-of-limits. No recovery action was necessary.

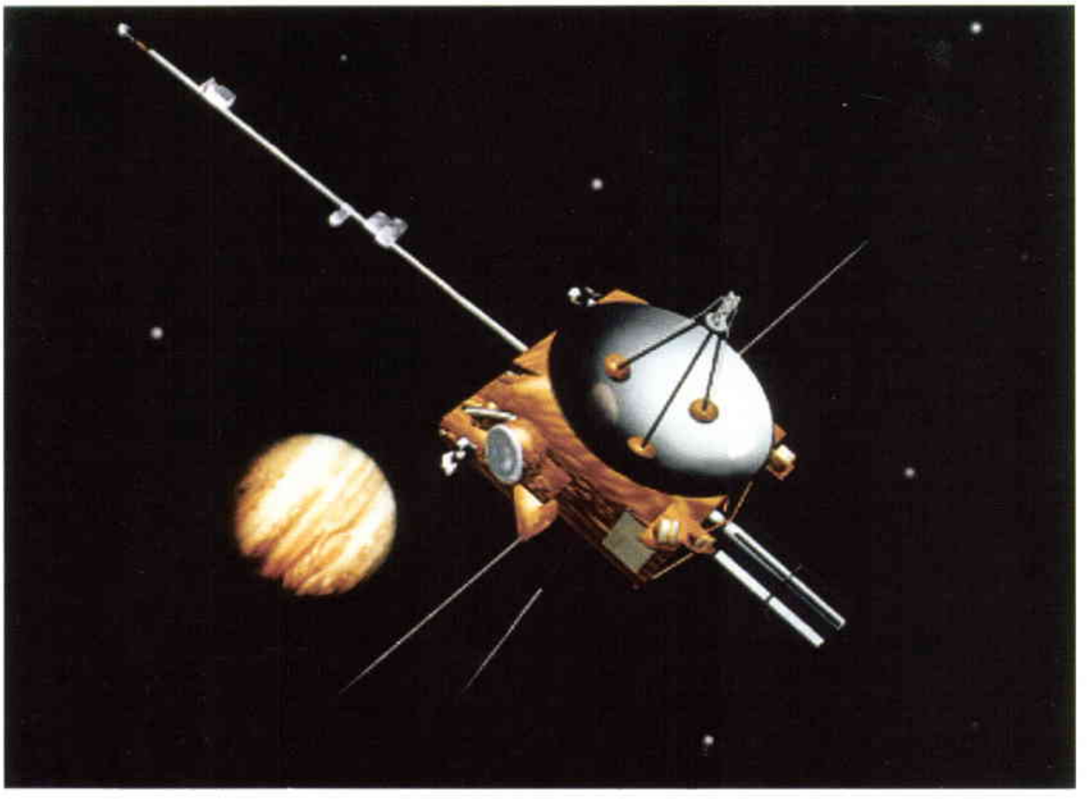
The period of most intense radiation dosage just after closest approach to Jupiter passed without further incident, and it was a great relief to know that the year of mission preparation and contingency analysis, and years of careful spacecraft design, had paid off. Apart from the above-mentioned payload incidents, there were no spacecraft anomalies during the month surrounding Jupiter encounter.

Table 1. Ulysses experiments

COSPIN	Cosmic-ray and Solar Particle Investigation
DUST	Dust experiment
EPAC	Energetic Particle Composition experiment
FGM/VHM	Magnetic-field experiment (Flux Gate Magnetometer/Vector Helium Magnetometer)
GAS	Interstellar Neutral Gas experiment
GRB	Solar X-Ray/Cosmic Gamma-Ray Burst experiment
GWE	Radio-science Gravitational Wave Experiment
HI-SCALE	Heliosphere Instrument for Spectra Composition and Anisotropy at Low Energies
SCE	Radio-science Solar Corona Experiment
SWICS	Solar-Wind Ion Composition Spectrometer
SWOOPS	Solar-Wind Observations Over the Poles of the Sun: ion and electron measurements
URAP	Unified Radio and Plasma Wave experiment

Table 2. Key encounter events

Date	Event description
Dec 3	Pre-Jupiter instrument calibrations began
Jan 13	GAS began Jupiter scan sequences
Jan 23	URAP Sounder reconfiguration
Jan 29	GAS ended Jupiter scan sequences
Jan 30	Start of continuous DSN coverage
Jan 31	Bit-rate change to 1 kbps scientific. Tape recorder switched-off
Feb 2	Bow-shock crossing detected
Feb 3	Beginning of one 70 m pass per day coverage
Feb 5	S-band transponder switched on
Feb 6	Beginning of continuous 70 m coverage
	HI-SCALE instrument returning high count rates
Feb 7	SWICS micro channel plate (MCP) bias changed
	SWICS detectors switched off
	COSPIN low-energy telescope (LET) detector switched off
	DUST reconfigurations
	HI-SCALE covers closed and experiment switched off
	GRB switched off
	All SWICS detectors switched on
Feb 8	EPAC switched off because of voltage out-of-limits
	SWOOPS-E, SWOOPS-I high voltages switched off
	EPAC/GAS switched off
	FGM range change to lower sensitivity
	3 h loss of commanding due to communications failure
	Data received from Jupiter closest approach (JCA) at 12:38 UTC
	FGM range change to lower sensitivity
	Io Plasma Torus crossing: radio-science investigation
	HI-SCALE post JCA switch-on sequence began
	GRB post JCA switch-on sequence began
Feb 9	SWOOPS-E, SWOOPS-I high voltages switched on
	EPAC/GAS switched on
	DUST reconfiguration
	GRB switched off due to high count rates
	COSPIN LET high voltages switched on
	S-band transponder switched off
	VHM switched on, FGM range changed to higher sensitivity
Feb 10	End of continuous 70 m coverage; return to one 70 m pass per day
Feb 11	SWOOPS-I reconfiguration for magnetosheath
Feb 12	GRB switched on and calibrated
Feb 16	URAP reconfigured to post-Jupiter mode.



The intense operations surrounding Ulysses' Jupiter encounter went like clockwork, thanks to the highly detailed encounter timeline and good communication with the science teams involved. An extensive and detailed timeline that all parties were aware of enabled real-time science changes and additions to be made easily, with a very fast response time.

Ground-segment performance

The entire ground segment performed almost flawlessly, providing near-perfect data return for the whole of the encounter period. Real-time data monitoring was always available via the SCMS, with the exception of a 15 min period 4 d after closest approach, when a disk failed on the real-time machine and a circuit breaker operated on the back-up machine. Both machines were back in operation in less than an hour. Near-real-time scientific data were produced routinely every hour by the Data Management Team.

For two passes at the beginning of February, commanding was shifted to the 70 m antenna at Goldstone, because of a failure of the 34 m antenna's transmitter. However, the only period during which the operations team could not command the spacecraft occurred shortly before closest approach, when a problem at Goldstone caused the loss of communications between JPL and the station for a little over 2 h.

Conclusions

The operation of the Ulysses spacecraft at Jupiter was the culmination of many years of activity, from spacecraft design and mission planning through to the coordination of the encounter activities and production of the detailed timeline. The smoothness of the operations and the scientific community's excitement about the results obtained as Ulysses passed the giant planet were an excellent reward for all of these efforts.

This mission phase required a completely different operations philosophy from that used during the earlier routine data-gathering phase, in that extensive real-time commanding was required. The outstanding support provided by the ground facilities, which performed almost flawlessly, was particularly critical in view of the need to disable the on-board tape recorders during this mission phase. Thanks are also due to the staff at JPL who helped and supported the many visitors to their laboratory during the period of the encounter.

The Ulysses spacecraft is now moving out of the ecliptic plane towards its prime mission, over the poles of the Sun.

The Ulysses Jupiter Flyby – The Scientific Results

R.G. Marsden & K.-P. Wenzel
ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

Introduction

The primary goal of the Ulysses mission, a joint venture of ESA and NASA launched in October 1990, is to explore for the first time the region of space above the poles of the Sun. Although the importance of this exploration to our understanding of the Sun's environment, the heliosphere, has long been recognised, the practical implementation of such a mission has, until relatively recently, been impossible.

Ulysses arrived at Jupiter 16 months after departing from Earth, having travelled nearly 1 billion kilometres in the ecliptic (ESA Bulletin No. 67 reported on the first scientific results from that in-ecliptic phase of the mission). Closest approach to the planet occurred at 12:02 UT on 8 February 1992. The primary aim of the flyby was to place the spacecraft in its final heliocentric out-of-ecliptic orbit with a minimum of risk to the onboard systems and the scientific payload. Scientific investigations at Jupiter were therefore a secondary objective of the mission. Nevertheless, the opportunity to study Jupiter's magnetosphere was exploited to the greatest extent possible. The results obtained have exceeded all expectations of the scientists involved.

While we are able to place satellites into a polar orbit around the Earth without much difficulty, the energy needed to launch a space probe into a polar orbit around the Sun is far greater. So much energy is required in fact, that even with the powerful launch vehicles available today, direct injection from the Earth cannot be achieved. This is because the Earth itself orbits the Sun at a speed of 30 km/s in a plane perpendicular to the desired solar polar orbit. The energy imparted to a space probe must cancel out this motion in addition to providing the correct polar trajectory.

A solar polar orbit can be achieved, however, by taking advantage of a gravity assist by another planet. Jupiter is the nearest body capable of meeting the requirements. The need to make use of Jupiter in order to carry out its primary mission has resulted in the recent flight of the ESA-built Ulysses spacecraft through the Jovian magnetosphere. Even with this gravity assist, the combined power of the Space Shuttle and three upper-stage rockets was needed to send the 370 kg space probe on its way. As it left the confines of the Earth's gravitational field, Ulysses was travelling at 11.3 km/s, making it the fastest interplanetary spacecraft ever launched.

Jupiter is a strongly magnetised, rapidly rotating planet. Its magnetosphere is the largest object in the solar system, a fact reflected in the long interval of 12 days, from 2 to 14 February (days 033 to 045 of 1992), that it took for Ulysses to travel through it. The large Galilean satellites (Io, Europa, Ganymede, and Callisto) are embedded within the magnetosphere and Io is known to be a prolific source of ions and neutral particles (Fig. 1). Ions, predominantly of sulphur and oxygen, are distributed around the orbit of Io to form a large torus. Electrons and ions from Io, Jupiter's ionosphere and the solar wind are all present and are transported throughout the magnetosphere. A substantial fraction of these particles are accelerated to extremely high energies to form intense radiation belts. Upstream of the magnetosphere, in the free-streaming solar wind, a detached bow shock forms which slows the solar wind and allows it to be deflected around the magnetosphere.

In short, a wide variety of complex physical phenomena are available for study.

The inbound trajectory (Fig. 2) was rather similar to those of the four spacecraft which flew past Jupiter previously: Pioneers 10 and 11 (1972, 1973) and Voyagers 1 and 2 (1979). In contrast to these missions, however, Ulysses reached high latitudes (40° north of Jupiter's equator) near closest approach. A unique aspect of the Ulysses flight path was the outbound passage through the

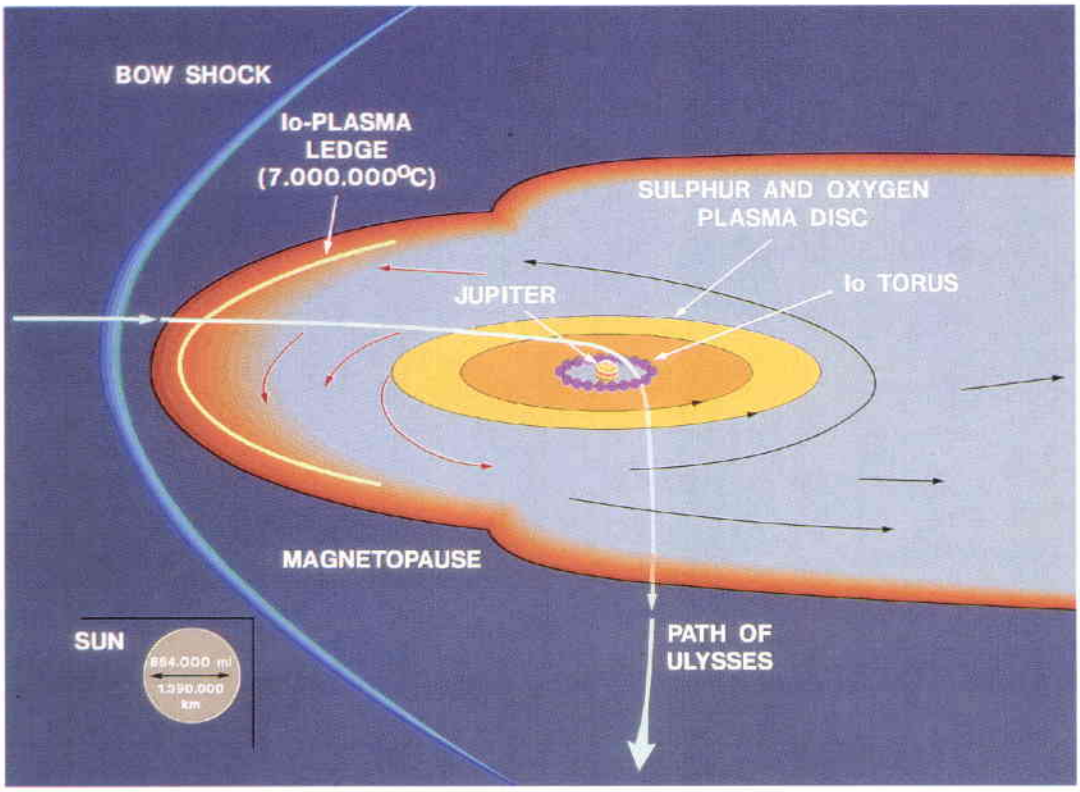


Figure 1. Schematic of Jupiter's magnetosphere. The solar wind, shown here approaching from the left, is deflected around the magnetosphere by the bow shock.

The outer boundary of the magnetosphere, called the 'magnetopause', is indicated. Major structural features inside the magnetosphere are shown.

hitherto unexplored dusk sector (18:00 h local time) of the magnetosphere, this time at high southern latitudes. Another unique aspect of the flyby was the penetration of the Io Plasma Torus (IPT), a few hours after closest approach, in a basically north-south direction which contrasted with the nearly equatorial Voyager-1 traversal.

In addition to this direct penetration, the spacecraft radio signal passed through the IPT for a significant length of time, making it possible to probe the electron density distribution in the Torus.

Although the instruments that make up the scientific payload (Table 1) are optimised for the conditions encountered in the solar wind, including their orientation on the spinning spacecraft, they have produced a wealth of new information relating to the Jovian magnetosphere. Some of the initial findings are summarised below. As is the case for the primary mission, many of the observations made in the magnetosphere by the different experiments are complementary in nature, making a correlative approach the most fruitful in terms of data interpretation. The operational aspects of the Ulysses Jupiter flyby are described in a companion article in this Bulletin (see pages 44—51).

Scientific results

Plasma and magnetic field

A fundamental contribution provided by the plasma (SWOOPS) and magnetic-field (FGM/VHM) experiments is the identification of the boundaries between the various magnetospheric regions encountered during the flyby (Fig. 3). This 'road map' is a useful tool that helps other experiments to place their observations in the correct context.

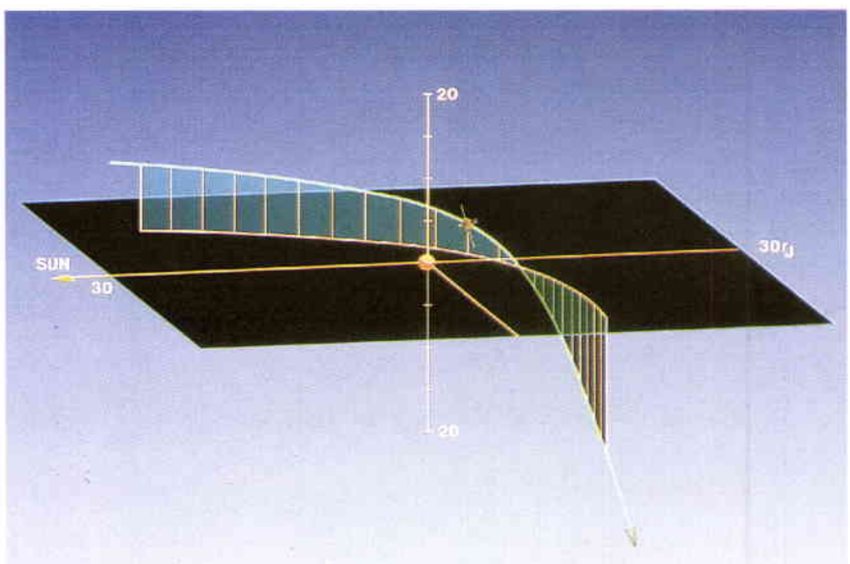


Figure 2. The trajectory of Ulysses past Jupiter. The open circle represents the point of closest approach at 6.3 Jovian radii (450 000 km) from the centre of the planet. Vertical lines denote intervals of 3 h relative to closest approach.

On 2 February, almost a week before closest approach, Ulysses crossed the Jovian bow shock at a distance of 113 Jupiter radii ($1R_j$ = 71 398 km) from the planet (Table 2). The inbound crossing occurred somewhat earlier than expected based on previous observations by the Voyager spacecraft.

A possible interpretation is that the solar-wind ram pressure was low, allowing the magneto-

Table 1. The Ulysses scientific payload

Investigation	Acronym	Principal Investigator
Magnetic field	FGM/VHM	A. Balogh Imperial College, London (UK)
Solar-wind plasma	SWOOPS	S.J. Bame Los Alamos Natl. Lab. (USA)
Solar-wind ion composition	SWICS	G. Gloecker Univ. of Maryland (USA) J. Geiss Univ. of Bern (CH)
Radio and plasma waves	URAP	R.G. Stone GSFC (USA)
Energetic particles, interstellar neutral gas	EPAC/GAS	E. Keppler MPAe, Lindau (D)
Low-energy ions and electrons	HI-SCALE	L.J. Lanzerotti Bell Labs. (USA)
Cosmic rays and solar particles	COSPIN	J.A. Simpson Univ. of Chicago (USA)
Solar X-rays and cosmic gamma-ray bursts	GRB	K. Hurley UC Berkeley (USA) M. Sommer MPE, Garching (D)
Cosmic dust	DUST	E. Grün MPK, Heidelberg (D)
Radio science (Io Torus)	SCE	M.K. Bird Univ. of Bonn (D)

Figure 3. Colour-coded spectrogram of the entire 15-day Ulysses flyby from the SWOOPS electron plasma instrument. Electron energy spectra summed over all look directions are displayed using the colour bar shown on the right to code the count rate.

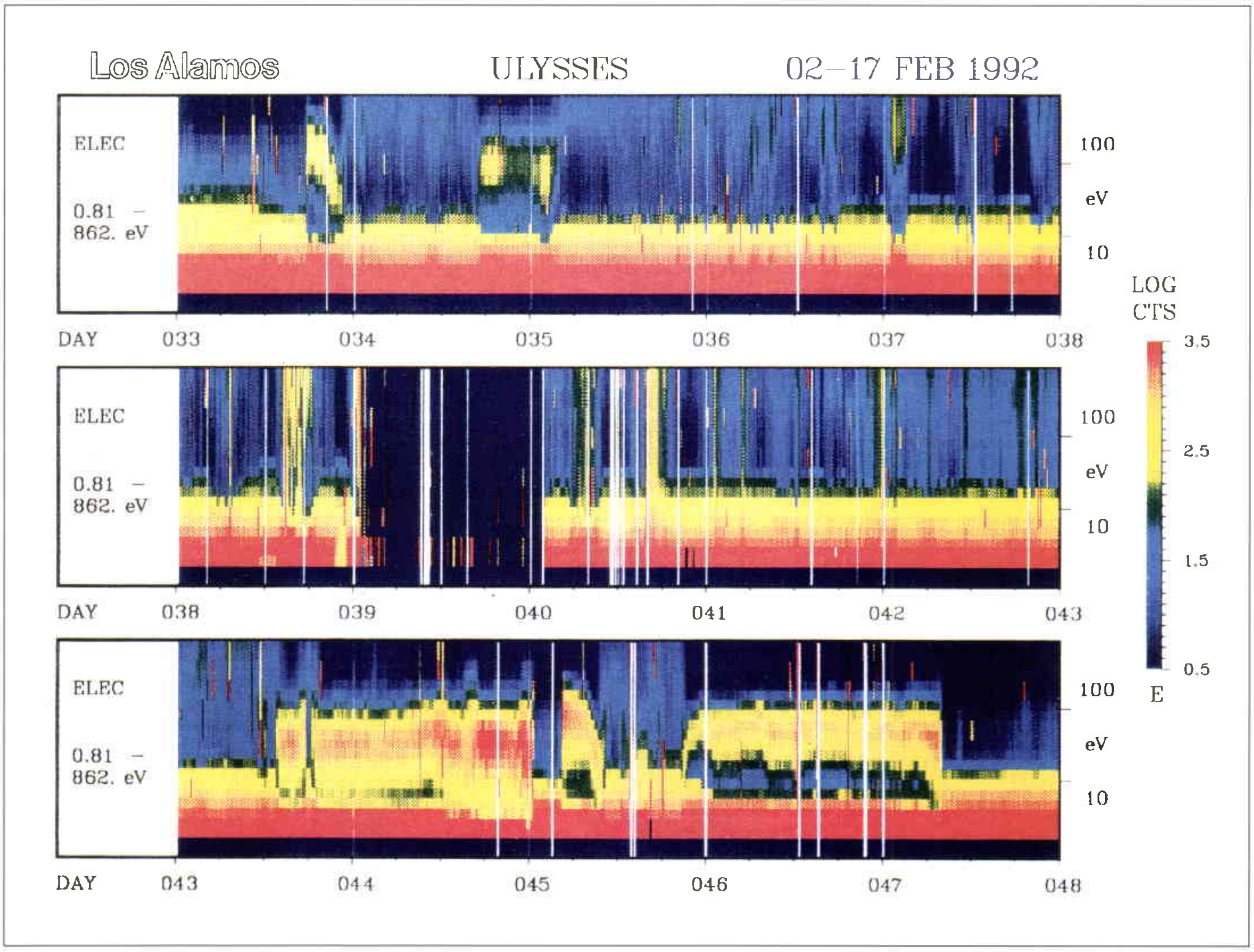


Table 2. Sequence of events during the Ulysses Jupiter flyby

Event	Time (day/hour/minute)	Distance (R_j)
Bow-shock crossing (inbound)	033/17:33	113
Magnetopause crossings (inbound)	033/21:30 – 035/04:00	110 – 87
Magneto-disc/plasma-disc crossings	036/06:30 – 037/22:00	67 – 36
High-latitude polar cap (possibly cusp)	038/22:30	15
	039/06:30	8.7
Closest approach	039/12:02	6.31
Observations of Io Plasma Torus	039/13:00 – 18:00	6.4 – 9.0
Observation of field-aligned currents, electron and ion streaming	041/01:00 – 043/13:00	35 – 82
Magnetopause crossings (outbound)	043/13:57 – 045/21:40	83 – 124
Bow-shock crossings (outbound)	045/00:37 – 047/07:52	109 – 149

sphere to temporarily 'inflate', causing the bow shock to 'stand off' further out from the planet. The magnetopause, the outer boundary of the magnetosphere, was first encountered only 4 h after the bow-shock crossing, at a distance of 110 R_j. The apparent proximity of these two boundaries, which are typically separated by 20 R_j, also suggests that they were moving rapidly outwards at that time.

On the outbound leg, multiple magnetopause and bow-shock crossings were observed as these boundaries moved inwards and then outwards across the spacecraft. This is again indicative of the 'elasticity' of the magnetosphere in response to changing solar-wind conditions.

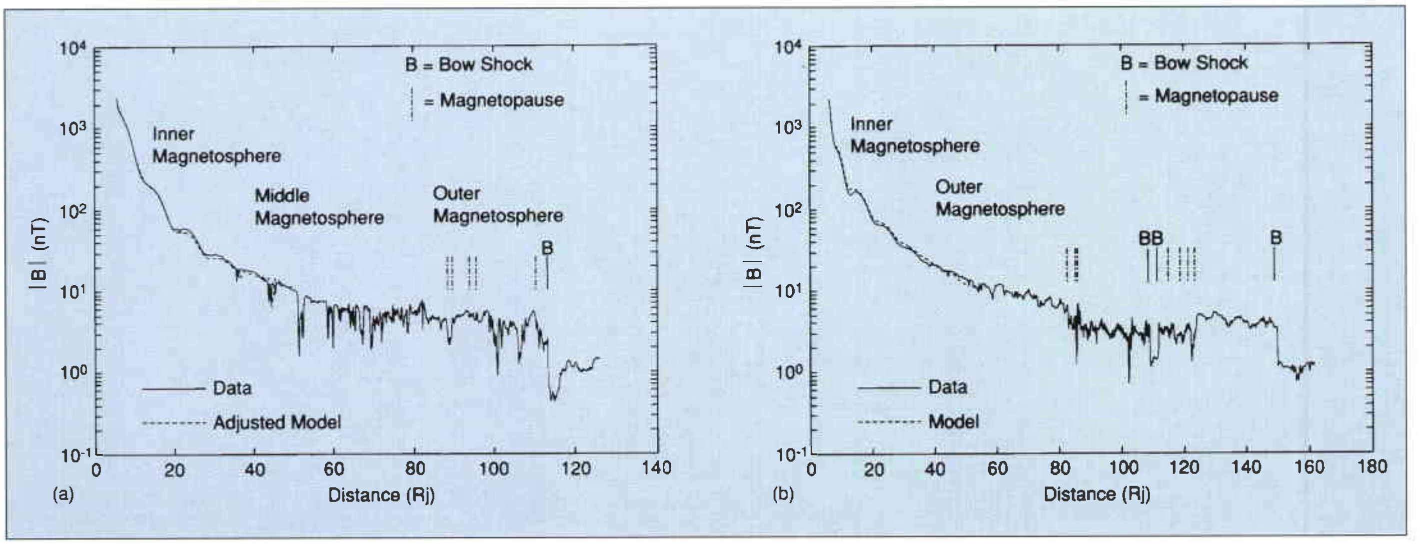
Other results to emerge from magnetic-field observations (Fig. 4) include the previously unknown configuration of the dusk-side field, which is strongly swept back towards the magnetotail, and the realisation that large-scale current systems are very important in determining the configuration and dynamics of the magnetic field.

Radio and plasma waves

Jupiter is a prolific source of natural radio waves, emitting at many wavelengths. The unique direction-finding capability and high sensitivity of the Ulysses radio and plasma wave (URAP) experiment have provided new insights and clues as to the origin of these radio signals (Fig. 5). For example, the so-called 'narrow-band kilometric' (nKOM) radiation has been found to originate from discrete, long-lived sources that are located in the outer regions of the Io Plasma Torus, and which rotate around Jupiter at slightly different rates.

Ulysses observations of the hectometric radiation (HOM) revealed narrow latitudinal beaming along the magnetic equator, and provided additional constraints on existing models for the source of this radio emission. Several bursts of radio emission showing a characteristic rapid drift in frequency, so-called 'Jovian type-III' events were detected with Voyager. With Ulysses, many events of this type have been recorded and they appear to be a major component of Jupiter's radio spectrum.

Figure 4. The magnetic-field magnitude measured by the FGM/VHM experiment during (a) the inbound pass, and (b) the outbound pass, plotted versus radial distance from the planet. The dashed line superimposed on the data denotes the predicted model field.



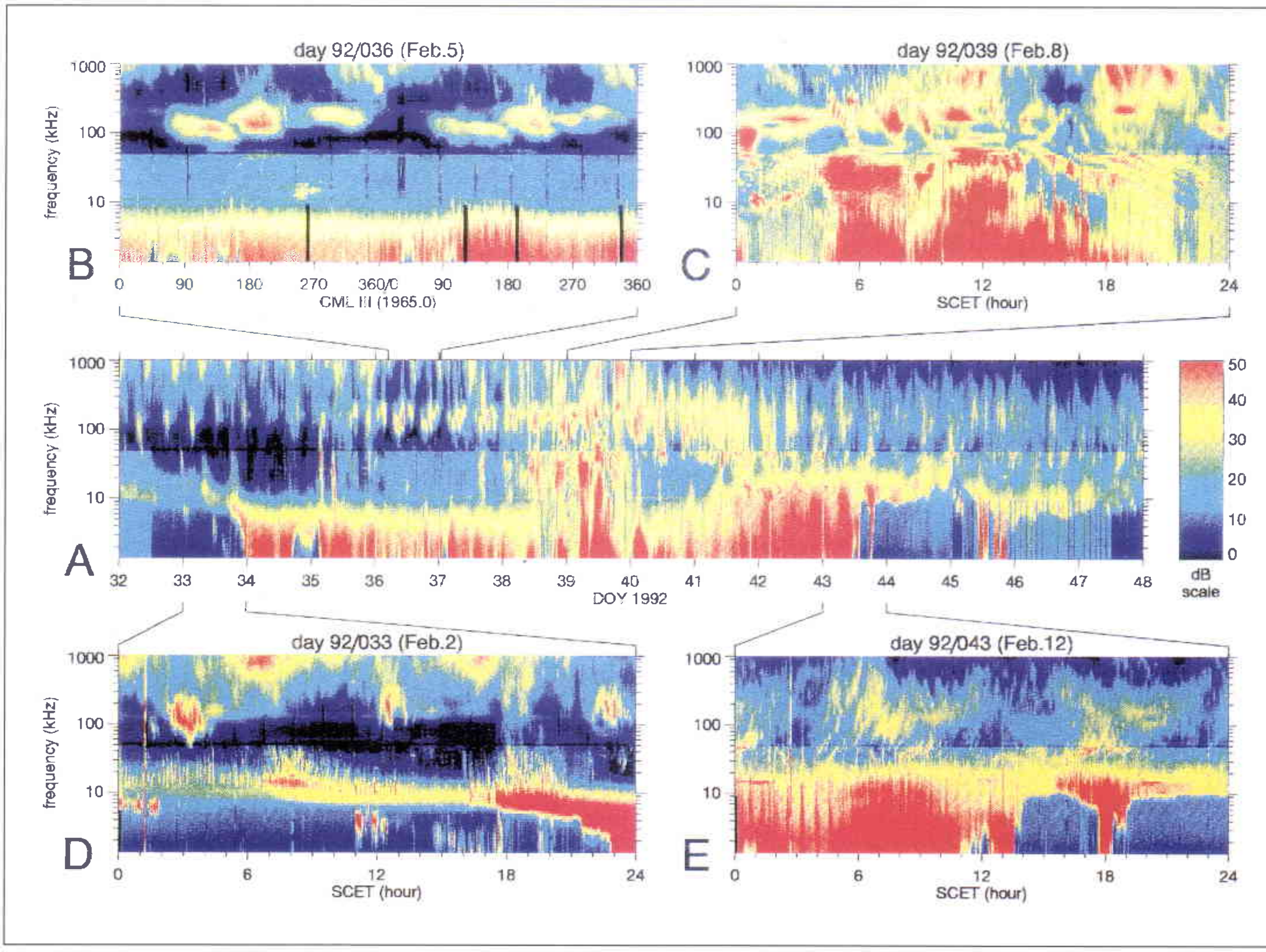


Figure 5. Overview of URAP radio and plasma-wave data during the flyby displayed as frequency versus time dynamic spectra, with relative intensity indicated by the colour bar on the right.

(A) 16 day overview centred on Closest Approach (CA, day 039).

(B) Two typical Jovian rotations before closest approach beginning at 05:00 SCET on 5 February.

(C) 24 h period centred on CA including passage through the Io Plasma Torus.

(D) 24 h period on the day of the inbound bow-shock and magnetopause crossing.

(E) 24 h period containing some of the outbound magnetopause crossings.

At the lowest frequencies, the Jovian continuum emission has been observed by URAP at large distances from the planet. Both the frequency range and intensity of the continuum have been seen to vary with solar-wind ram pressure, thus providing a unique long-term remote monitor of solar-wind conditions at Jupiter.

Plasma composition

The Ulysses solar-wind ion composition (SWICS) experiment has provided important new data on the composition of the magnetospheric plasma, in particular information on the charge states of the various ions (Fig. 6). These measurements give new insights into the sources and 'life history' of the Jovian plasma. Material from three sources, the solar wind, the planet itself and the volcanic satellite Io (Iogenic ions) can be traced by observing ions specific to each source.

Large-scale mixing was observed to occur, with significant numbers of solar-wind and Iogenic ions being found in all regions investigated. The implication is that solar-wind plasma penetrates deep into the magnetosphere and Iogenic ions travel outwards to its outer reaches, both at low and high latitudes. These results provide important tests for models of plasma circulation, transport and loss from the magnetosphere.

Io Plasma Torus

The Io Plasma Torus (IPT), a doughnut-shaped ring of plasma rotating with the planet at the orbit of Jupiter's moon Io, was an object of special interest during the flyby. Its properties were measured both directly by the URAP instruments, and also remotely by the Ulysses Radio Science team.

The IPT consists largely of ionised oxygen and sulphur atoms released as a neutral cloud by Io's volcanoes. The Ulysses measurements, taken a few hours after closest approach as the spacecraft crossed Jupiter's magnetic equator, indicate that the electron density of the IPT in the current epoch matched model predictions based on the older Voyager results quite well (Fig. 7). On the other hand, the longitudinal distribution of plasma seen by Ulysses showed asymmetries not expected from the

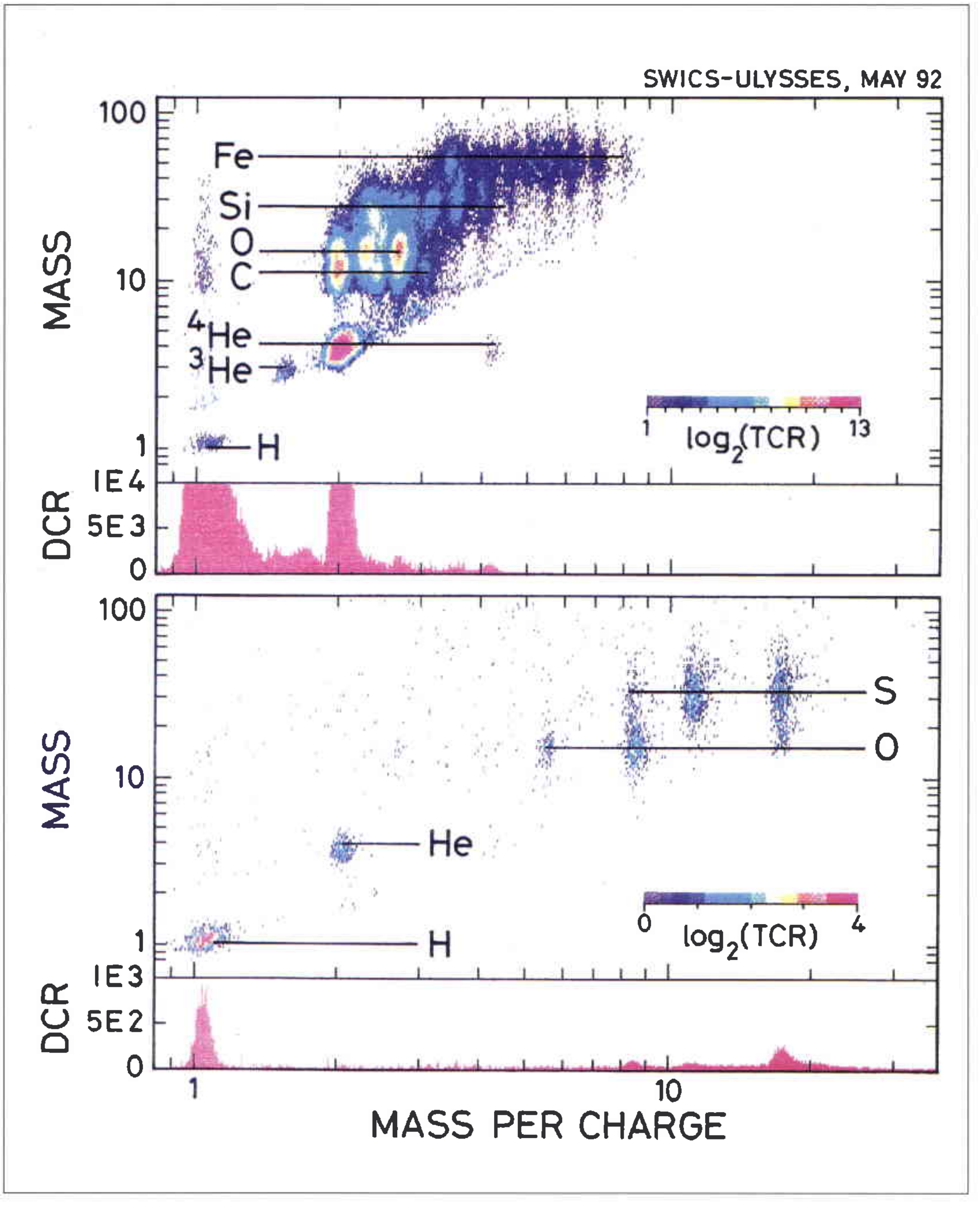


Figure 6. SWICS ion-composition data plotted in the form of a mass versus mass-per-charge matrix of solar wind (top) and Jupiter magnetospheric plasma (bottom). The change in charge state and elemental composition is striking.

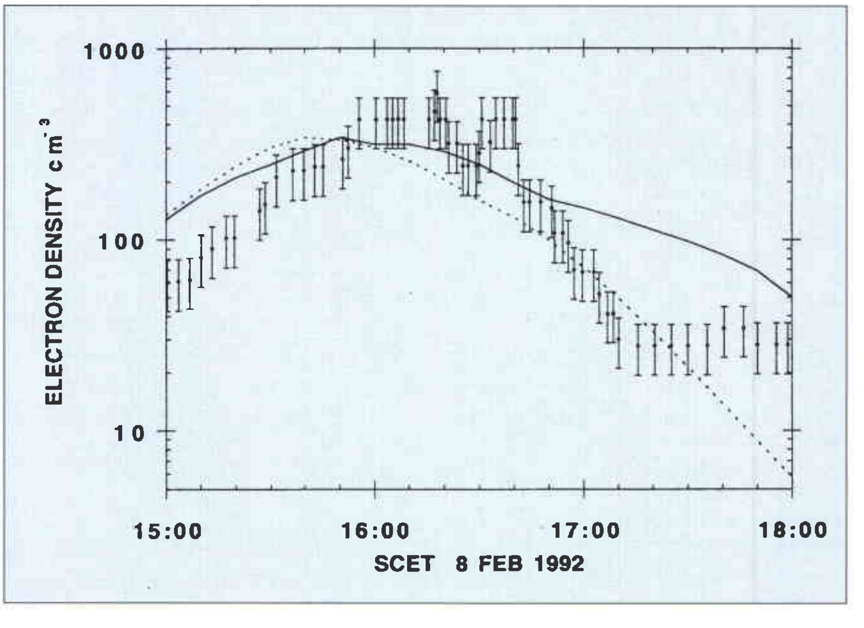


Figure 7. Electron densities within the Io Plasma Torus (IPT) as determined by the URAP experiment.

For comparison, model predictions based on Voyager data are also shown.

Voyager data, which, as mentioned in the Introduction, were taken in a different region of the IPT.

Energetic particles

The energetic-particle intensities measured by the Ulysses instruments during the flyby (Fig. 8) were generally lower than observed by the Voyager spacecraft. A major discovery during the outbound pass was the existence at high latitudes of very strong, counter-flowing streams of electrons and ions, constituting large currents that apparently feed into the auroral regions.

Measured principally by the HI-SCALE experiment, these field-aligned particle beams are tightly confined to magnetic field lines which, as noted above, appear to be swept strongly tailward. In the same regions, the COSPIN experiment observed periodic bursts of MeV electrons flowing away from the planet (Fig. 9). Preliminary estimates indicate that these bursts may represent a significant fraction of the population of relativistic electrons found in interplanetary space. Data from many of the Ulysses experiments point to the fact that the dusk-side magnetosphere, where the fields and plasmas rotate from the compressed day side into the magnetotail, is highly dynamic. Furthermore, signatures in the energetic particle data indicate that the high-latitude region of the magnetosphere appears to be dominated by the interaction of the solar wind with the planet's magnetic field.

Polar-cap region

Because of its high-latitude trajectory, Ulysses was able to investigate the poleward extent of the Jovian radiation belts that contain durably trapped energetic electrons and ions. One surprising finding was that even close in to the planet (approximately 9 Jupiter radii), Ulysses apparently made an excursion out of the radiation belts at magnetic latitudes of only 48°. Signatures in the data from many of the instruments are consistent with Ulysses having passed through a region in which magnetic field lines from the Jovian polar cap at one end were connected to interplanetary magnetic field lines at the other end.

For example, the energetic-particle sensors registered counting rates close to interplanetary background levels, while the SWOOPS plasma instruments noted a simultaneous drop-out in the magnetospheric electron population for a period of 1.5 h. URAP DC electric-field measurements indicate a drop in the plasma flow speed to very low levels.

Supporting observations

An important accompaniment to the flyby was a set of supporting observations carried out by ground-based observers,

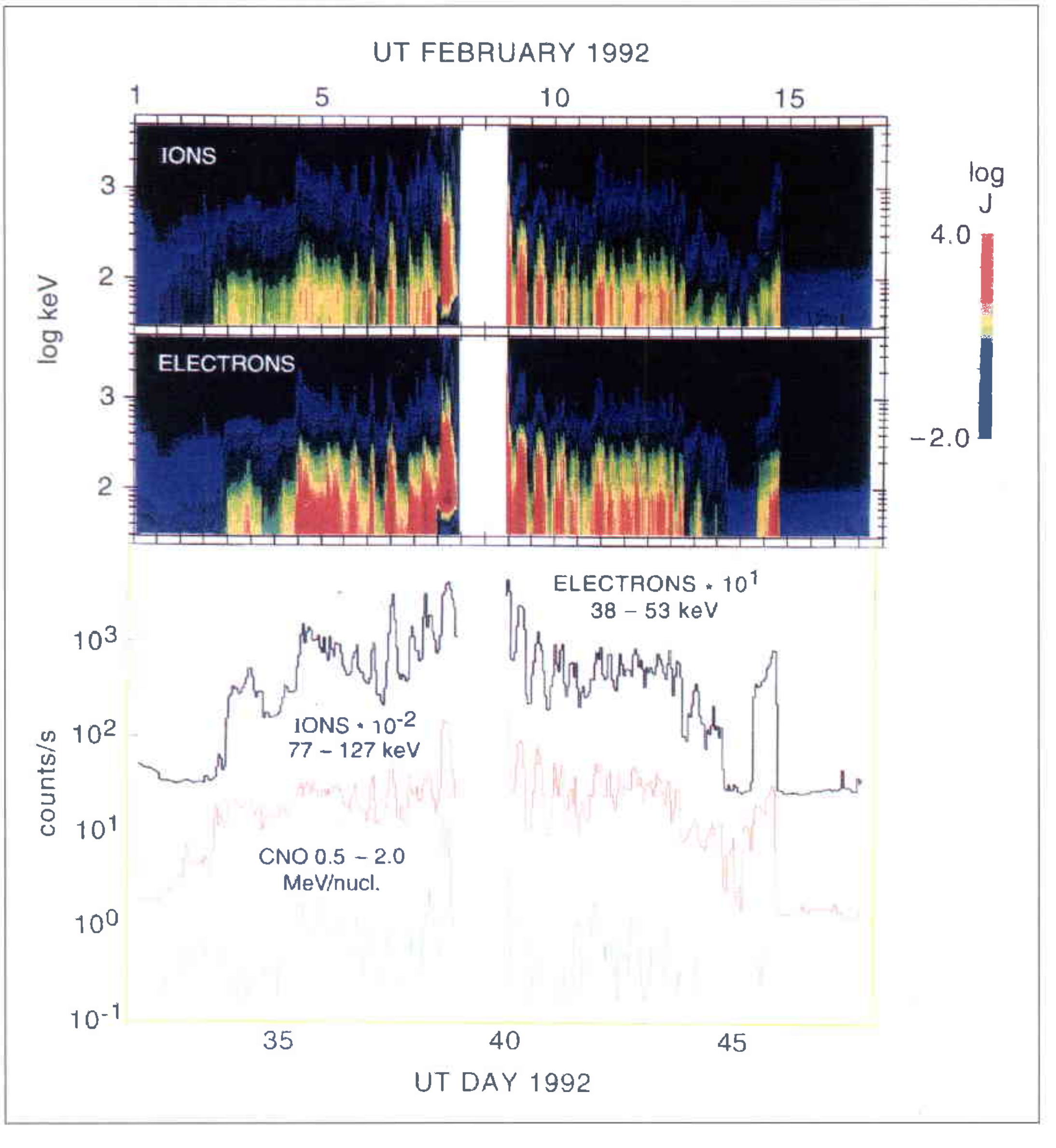


Figure 8. Overview of HI-SCALE measurements of ions and electrons in Jupiter's magnetosphere displayed as an energy spectrogram (upper panel) and counting rates (lower panel).

particularly those involved in the Jupiter-Watch programme, as well as observers making use of Earth-orbiting spacecraft, including the Hubble Space Telescope (HST) and the International Ultraviolet Explorer (IUE). Using ESA's Faint-Object Camera onboard HST, European scientists obtained an image of the polar aurora surrounding Jupiter's north pole just 15 h after Ulysses' closest approach (Fig. 10).

This type of remote sensing of emissions from Jupiter's auroral regions, and the IPT, has helped to establish the context in which the flyby took place.

Conclusions

Although the study of the Jovian magnetosphere was not a primary mission objective, the recent flyby of the giant planet by the Ulysses spacecraft has produced a wealth of new observations that constitute a major contribution to our understanding of this complex and dynamic plasma environment.

Following the flyby, all spacecraft systems and the scientific instruments were checked out thoroughly and found to be in good health. Having therefore emerged from Jupiter's hostile radiation environment unscathed and perfectly on course, Ulysses has now begun the most exciting phase of its mission.

Moving out of the ecliptic towards the Sun's southern polar regions, it has started its exploration of the high-latitude heliosphere. Helped on its way by the immense gravitational field of Jupiter, Ulysses will pass over the southern pole in September 1994 and continue on to the northern polar regions, which it will reach one year later.

Based on the exciting results obtained to date both during the in-ecliptic phase and at Jupiter, we can expect a rich scientific harvest from the primary phase of the mission, as well as some surprises no doubt!

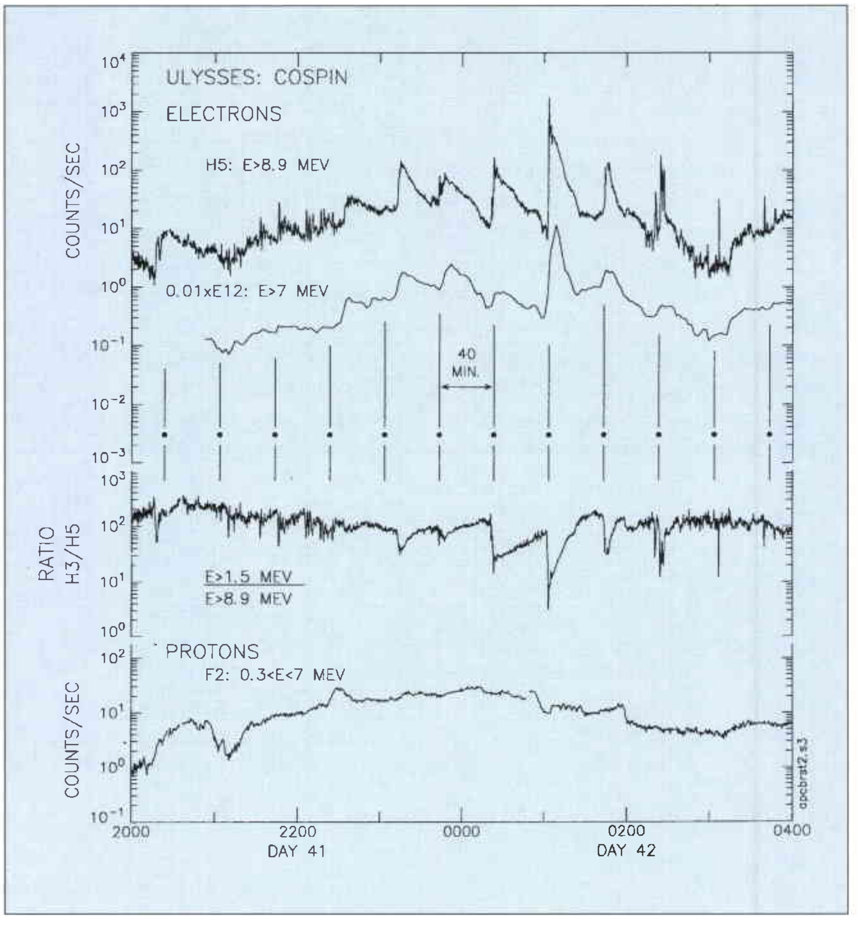


Figure 9. Data from the COSPIN experiment showing a quasi-periodic sequence of electron bursts observed on the outbound pass in the dusk sector of the magnetosphere. Shown for comparison are the simultaneous proton measurements.

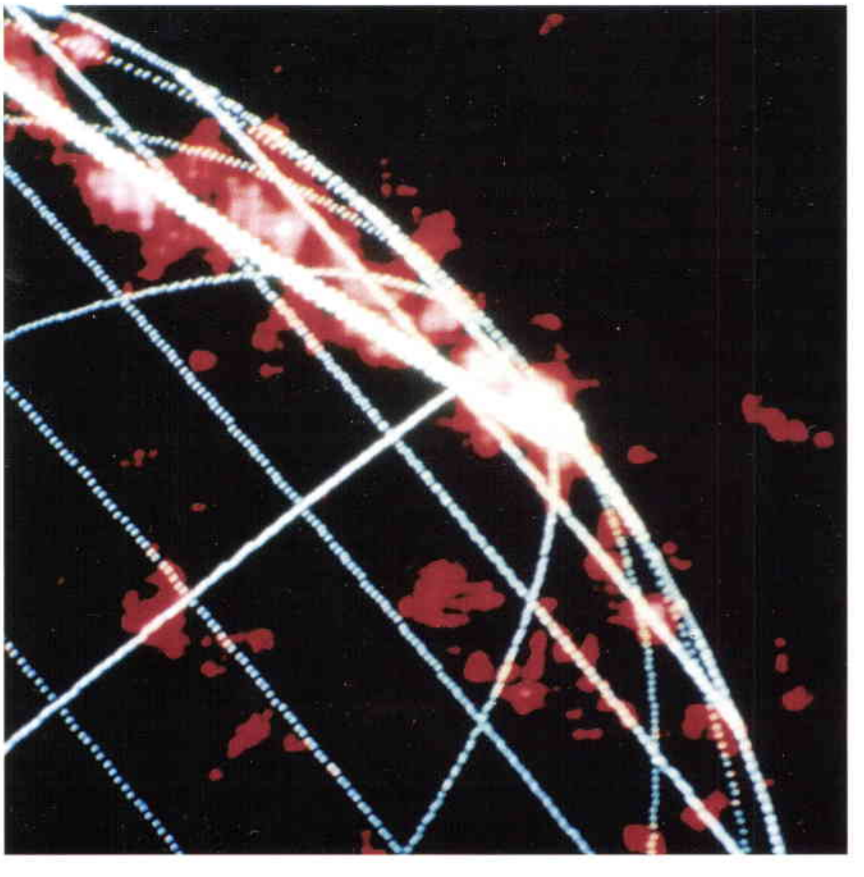


Figure 10. False-colour image of the northern polar region of Jupiter observed with ESA's Faint-Object Camera onboard the Hubble Space Telescope a few hours after the Ulysses flyby.

The Giotto Extended Mission to Comet Grigg-Skjellerup: Summary of Preliminary Results

G.H. Schwehm
GEM Project Scientist, ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

Comets, besides providing us with clues as to the origin of the Solar System, the Earth and probably also star formation in general when we study their structure and chemical composition, serve as 'space laboratories' for the study of magneto-hydrodynamic processes. The latter occur in the hot gases or plasmas containing charged particles or ions along with magnetic fields, such that the clouds of gas are partially or primarily controlled by the magnetic fields. The investigations of the Giotto Extended Mission, or 'GEM' (see ESA Bulletin No. 70, pp. 55–59 for a detailed description of the second encounter mission), have provided excellent new data concerning the interaction of the solar wind with a non-magnetised body in space.

Introduction

Space missions to date have provided only a snapshot view of three of perhaps billions of comets with possibly differing natures, origins, and physical histories. Grigg-Skjellerup, an old, low gas producing comet ($6 \times 10^{27}\ s^{-1}$) provided the lower boundary case when compared with Comet Giacobini-Zinner ($2 \times 10^{28}\ s^{-1}$), the first comet studied in-situ by a spacecraft, the International Cometary Explorer (ICE), on 11 September 1985, and the very much more active Comet Halley ($6.9 \times 10^{29}\ s^{-1}$) visited by a fleet of spacecraft, including Giotto, between 6 and 25 March 1986.

The comparative study of these three comets, with their wide variations in gas production rates, was deemed a prime objective when planning the Giotto Extended Mission. With the results achieved with Giotto at Comet Grigg-Skjellerup, it should indeed be possible to improve our knowledge of comet/solar-wind interaction quite substantially.

The encounter

After the second re-activation of the Giotto spacecraft on 4 May 1992, the experiment teams had to be patient until mid-June, when enough on-board power became available to begin checking-out the individual instruments, and the Halley Multicolour Camera in particular. It was concluded in June, however, that the payload's status had not changed (Table 1) vis-a-vis the findings after the spacecraft's first reactivation in 1990, and it became clear that we would not be able to acquire images of another cometary nucleus. Table 2 summarises the key mission parameters for the Comet Grigg-Skjellerup fly-by.

Table 1. Status of the Giotto payload for the Comet Grigg-Skjellerup encounter

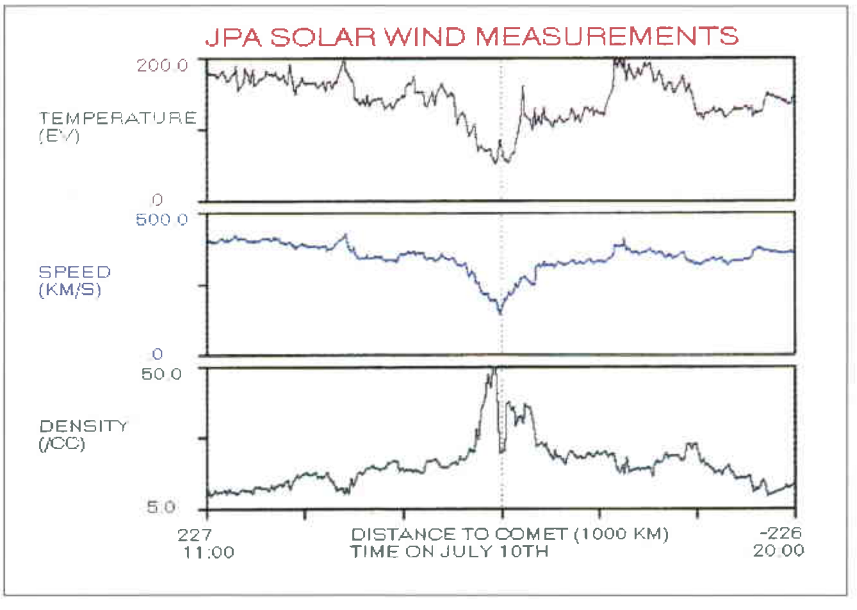
Instrument	Status	Active during G-S encounter
Halley Multicolour Camera	Aperture blocked; baffle missing; blind	No
Neutral Mass Spectrometer	Detectors dead	No
Ion Mass Spectrometer	HERS: high-voltage damage,	No
	HIS: no damage	Yes
Particulate Impact Analyser	Mass spectrum slightly degraded	No
Dust Impact Detection System	Some detectors showing increased noise	Yes
Optical Probe Experiment	No damage	Yes
Magnetometer	No damage	Yes
Johnstone Plasma Analyser	High-voltage problems on one sensor	Yes
Rème Plasma Analyser	Cold ion composition: high-voltage damage	No
	Damage to electron electrostatic analyser	Yes
Energetic Particle Analyser	No damage	Yes
Giotto Radioscience Experiment	Not applicable	Yes

To provide the best possible scientific coverage, all of Giotto's on-board sensors that could still provide meaningful data were operated during this second encounter, despite the fact that available on-board power was by now marginal as far as running the full functional payload complement was concerned. The heliocentric encounter distance of 1.01 AU at Comet Grigg-Skjellerup compared with the 0.9 AU at Comet Halley meant that there was about 20% less power available from the spacecraft's solar array. The data collected by all of the instruments that were active, however, fully justified this decision.

Table 2. Key mission parameters for the Comet Grigg-Skjellerup Fly-by [Halley fly-by data included for comparison]

	Grigg-Skjellerup	Halley
Encounter date	10 July 1992	14 March 1986
Relative fly-by velocity	13.99 km s^{-1}	68.37 km s^{-1}
Fly-by distance	200 km	596 km
Heliocentric distance	1.01 AU	0.90 AU
Geocentric distance	1.43 AU	0.96 AU
Distance above/below ecliptic	0.10 AU below	0.02 AU below
Angle between spin axis and relative velocity vector	68.8° (at 89.6° SAA*)	0° (at 107.2° SAA*)

* SAA = Solar-Aspect Angle



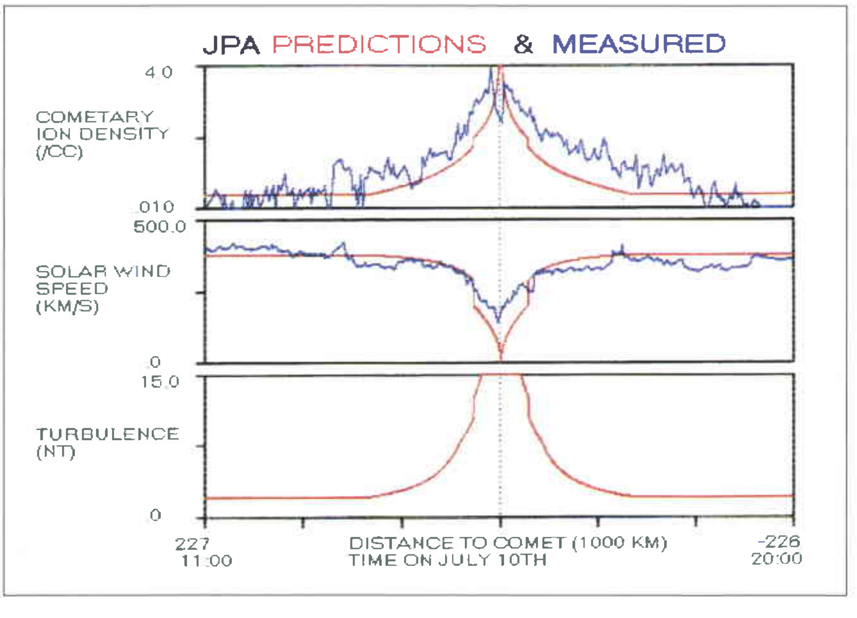


Figure 1. Summary of the JPA instrument's solar-wind and cometary plasma parameter measurements for 10 July 1992, between 11:00 and 20:00 UTC

The lower encounter velocity (14 km/s) at Grigg-Skjellerup and the angle of approximately 70° between the spacecraft's spin axis and relative velocity vector are especially noteworthy since they mean that dust grains released from the comet were hitting Giotto's dust protection shield at almost grazing incidence, and that the solar array mounted on the spacecraft's cylindrical body was fully exposed to the impinging dust.

During the evening of 9 July 1992, the full payload complement was switched on in encounter configuration and made ready to 'feel and smell', but unfortunately not see, Comet Grigg-Skjellerup.

The last-minute information that the teams at ESA's European Space Operations Centre (ESOC) near Frankfurt (D) had received in near-real-time from the European Southern Observatory's telescope at La Silla, in Chile, had indicated that the comet had brightened during the days just before the encounter, that it was exhibiting a reddish hue (an indication that dust was being released by the nucleus), and that there was a visible coma of some 20 000 x 20 000 km^2, and perhaps even an indication of a tail developing. All of these were very good omens for a successful encounter, with a predicted closest approach distance of some 600 km.

The scientific results

The Johnstone Plasma Analyser (JPA) aboard Giotto detected the first signs of the comet, namely pick-up water-group ions, at a distance of 440 000 km from the nucleus. The fundamental process involved in the interaction between a comet and the solar wind is mass loading of the solar wind by cometary ions. Neutral molecules of cometary origin are ionised by solar radiation within the solar-wind flow at large distances from the comet. Once these relatively massive ions have been implanted in the flow, they are accelerated by the inter-planetary electric field into cycloidal orbits moving perpendicular to the magnetic field.

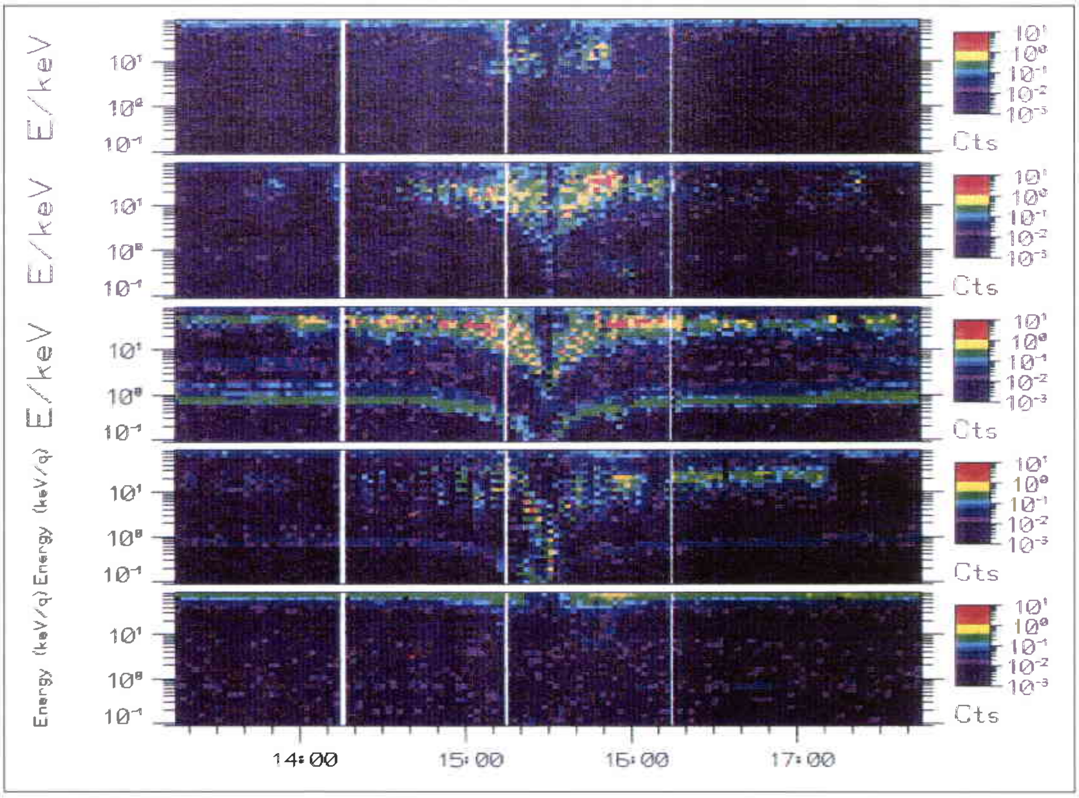


Figure 2. Display of the JPA Implanted Ion Sensor time-of-flight measurements for different viewing directions. It shows clearly the evolution in implanted cometary ions (mass 12-22 amu) with respect to the protons (mass 1 amu) mainly due to the solar wind's domination at large distances from the nucleus

The energy and momentum given to the cometary ions comes from the solar wind, which is therefore decelerated by increasing amounts as the comet's nucleus is approached.

This mass-loading effect is clearly apparent in the measured reduction in solar-wind velocity. A directional change in the velocity vectors of the solar wind close to the inner regions of the coma was also clearly observed by the JPA instrument. From these measurements, the experimenters derived a gas production rate (*Q*) for Comet Grigg-Skjellerup at the time of the encounter of the order of 6×10^{27} s^{-1}, a value that proved to be in excellent agreement with the $6.8 \pm 0.9 \times 10^{27}$ s^{-1} derived from the Magnetometer (MAG) data as early as 10:00 UTC on 10 July by using a different approach.

The Magnetometer detected pick-up-generated wave fields out to at least 270 000 km. These waves had a period of the order of 70 s and increased in amplitude, with simple clean wave forms. The waves were left-hand polarised, in contrast to those at Comets Halley and Giacobini-Zinner, where they were right-hand polarised. When Giotto was about 20 000 km from the nucleus, magnitude variations in the magnetic-field properties were detected, but these variations were smooth, indicating a bow wave some 19 900 km from the nucleus rather than a bow shock.

The Plasma Analyser, on the other hand, gave all the indications of a bow shock in the plasma domain at that distance. However, with the spacecraft outbound at 25 400 km from the comet, a strong bow-shock crossing was seen in both instruments. Close to the nucleus, the magnetic field strength increased to 89 nT – higher than at Halley – but no magnetic cavity was detected. This was no surprise as the cavity, if it existed at all at Grigg-Skjellerup, was predicted to extend only to about 60 km around the nucleus.

The Energetic Particle Analyser (EPA) measured the energetic charged particles ($E > 60-260$ keV) in the cometary environment. The highly anisotropic fluxes detected show a strong streaming in the anti-solar direction. Three regimes displaying, respectively, smooth flux variations, burst-like enhancements and wave-like structures, were identified. The ions recorded were a mixture of solar-wind protons and cometary water-group ions, the latter displaying energies greatly exceeding the maximum attributable to the pick-up process alone. The wave-like structure seen in the measurements represents the response of the particles to ambient ion-cyclotron waves, and there is an excellent correlation with some of the magnetometer data.

At almost 50 000 km from the nucleus (Fig. 4), the Optical Probe Experiment (OPE), measuring the brightness and polarisation of

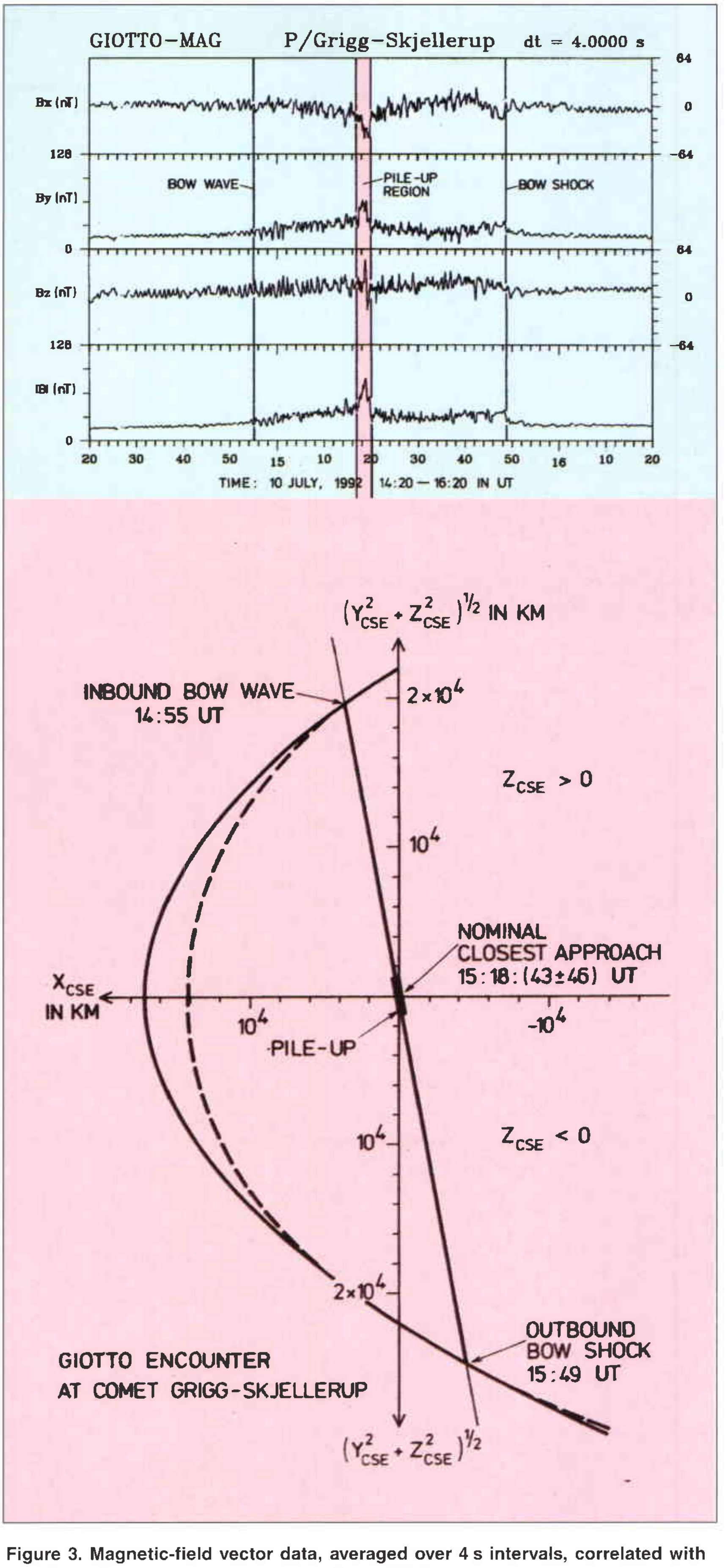


Figure 3. Magnetic-field vector data, averaged over 4 s intervals, correlated with the Giotto fly-by trajectory at Comet Grigg-Skjellerup in comet-centred solar ecliptic coordinates. A paraboloid (solid) and a constant mass-loading surface (dashed) have been fitted to the inbound bow wave and the outbound bow-shock crossing

the sunlight scattered by the cometary dust particles and some broadband molecular emissions, detected a brightening in the gas channels. The dust coma was entered at a distance of about 17 000 km from the nucleus. From the intensity distribution in the inner coma, a miss distance smaller than 200 km was derived and there is a clear indication that the spacecraft passed the nucleus on the evening side. The peak brightness was recorded at 15:30:43 UTC (ground receive time), with an uncertainty of only 3 sec. The secondary peak in Figure 4 is a real event which is being studied currently, but no explanation has yet been found. In the outer coma, an average polarisation of the order of 21% was found, whereas in the inner coma (closer than 1500 km) this value changed to about 11%, indicating that there is an evolution in dust properties within 2000 km of the nucleus.

The Dust Impact Detection System (DID) detected three dust particles shortly after closest approach, with masses of 100, 2 and 20 µg, very much in line with predictions. In this context, one has to bear in mind the reduced sensitivity of the DID detectors due to the lower impact velocity and the unfavourable impact angle at Grigg-Skjellerup compared with Comet Halley.

A drag-induced deceleration of the spacecraft was detected by Giotto's Radio-science Experiment (GRE) during the encounter. Two-way Doppler and ranging measurements conducted before and after the fly-by revealed a total change in the spacecraft's radial velocity (along the line-of-sight to Earth) of 0.4 mm/s. Assuming inelastic momentum transfer, this deceleration corresponds to a total effective cometary mass collected of approximately 39 mg. This caused a small nutation of the spacecraft around closest approach.

At the same time, the Weilheim and Madrid ground stations reported a slight fluctuation in signal levels and a sudden reduction of 120–140 Hz in the Doppler residuals. However, the estimated velocity reduction due to the dust impacts, deduced from the two-way Doppler measurements taken after the encounter, was of the order of 1 mm/s relative to the comet, equivalent to an increase in the observable Doppler shift on ground of 0.01 Hz, which is in agreement with the GRE result. This, however, has to be treated with a certain amount of caution as the error in the measurement is comparable with the estimated value.

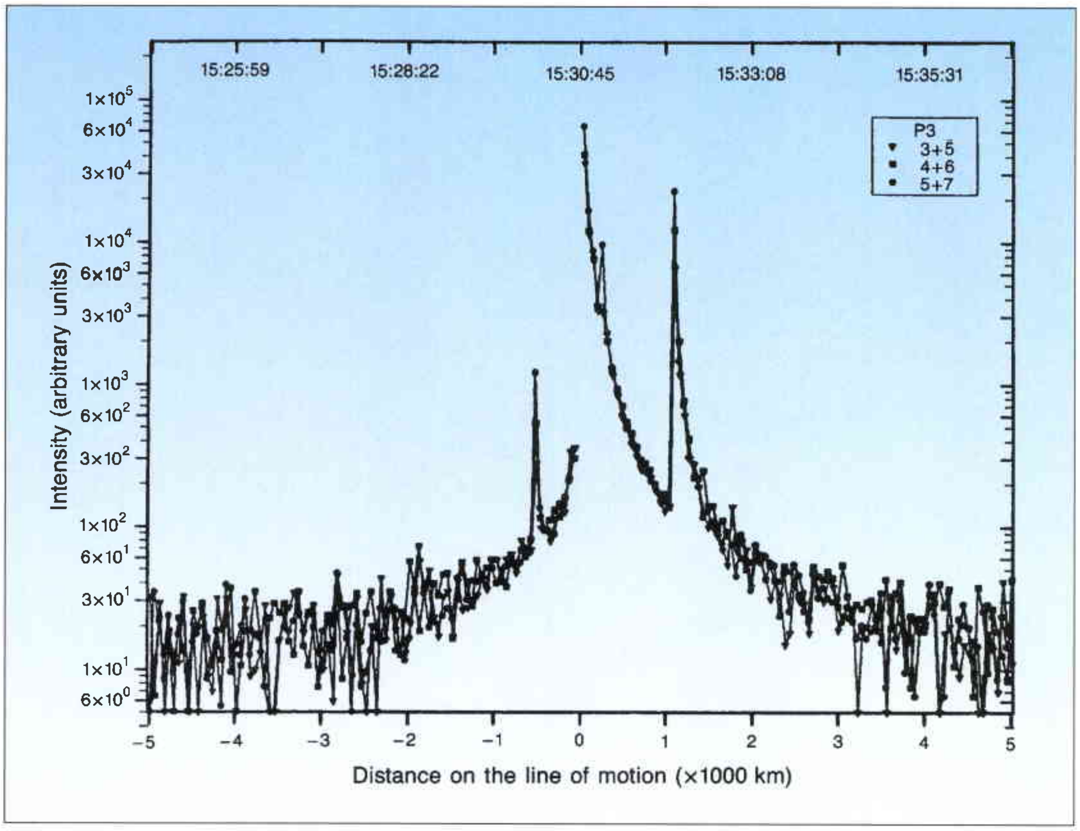


Figure 4. The brightness distribution in the coma of Comet Grigg-Skjellerup due to the scattering of sunlight by cometary dust particles, as a function of distance from the nucleus. The gap in data is caused by the loss of one science data frame when the spacecraft was hit by a large dust particle. No explanation has yet been found for the secondary peak, but it is an actual measurement and not an error in the data

The conclusion is that the deceleration must have been very small and therefore hardly detectable from the two-way Doppler data. The frequency shift observed at encounter could be explained as an instantaneous variation in the frequency of the on-board oscillator, correlated with the comet interaction.

These in-situ measurements are complemented by a number of ground-based and IUE observations.

Mission termination

After a period of seven years in orbit around the Sun, Giotto operations were officially terminated on 23 July 1992, after the completion of final orbit adjustments and after configuring the spacecraft for its third hibernation.

On its present course, Giotto will pass 219 000 km above the Earth's surface on 1 July 1999, 14 years after the spacecraft's launch. Future operation of the spacecraft is considered doubtful, partly because the fuel remaining (4 ± 3 kg) is insufficient for anything more than an Earth or Moon fly-by in 1999, and partly because of the age by then of both the spacecraft itself and the ground systems used to support the GEM mission.

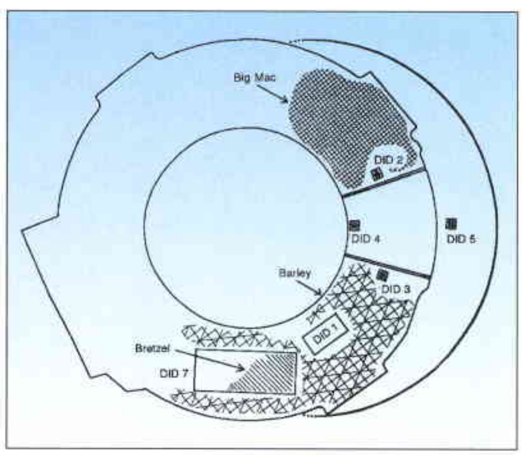
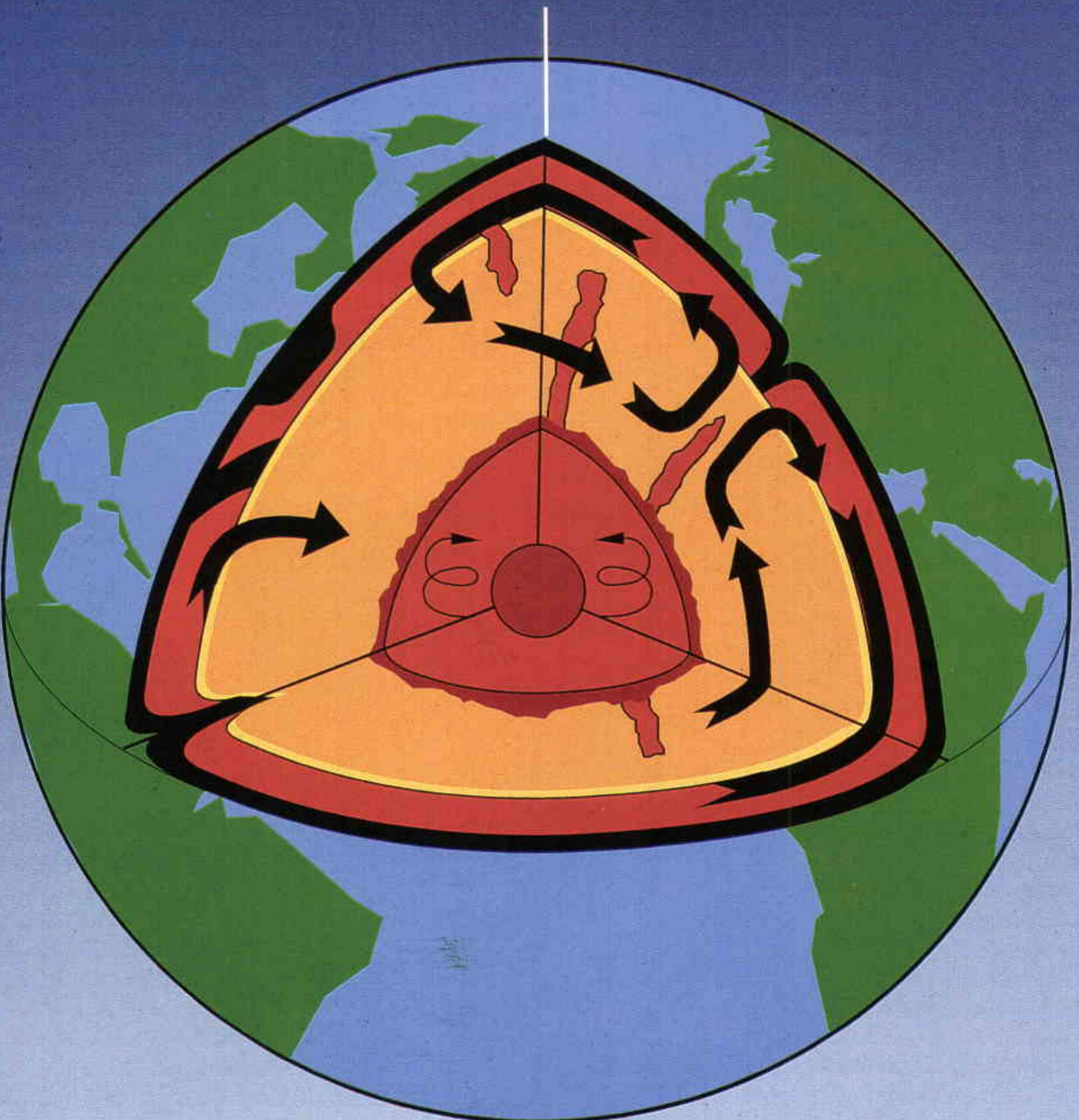


Figure 5. DID sensor configuration on the front and rear meteoroid bumper shields of the Giotto spacecraft. Possible locations for the three impacts (named in a moment of scientific euphoria!) are shown

Acknowledgement

The success of the Giotto Extended Mission has been due to the excellent joint efforts of the teams at ESOC, the Experimenters, and the small Project Team at ESTEC. The scientific results that have been achieved are a tribute to their dedication and hard work. All of those who have been involved can look back with pride on the achievements of Giotto's missions to Comets Halley and Grigg-Skjellerup, which have truly been milestones in our exploration of the Solar System.



Schematic of a dynamic Earth model. Arrows emphasise the dynamic nature of the interior where convection in the mantle is responsible for up-welling and down-welling currents. Gravity and magnetic data from Aristoteles are crucial if these and other such geophysical processes are to be modelled

Probing the Earth from Space – The Aristoteles Mission

M. Schuyer, P. Silvestrin & M. Aguirre
Earth Observation Projects Department, ESTEC, Noordwijk, The Netherlands

The Aristoteles* mission has been under study by the Agency since 1987. Its aim is to provide global models of the Earth's gravitational and magnetic fields with high spatial resolution and accuracy. Following earlier discussions, in 1990 NASA confirmed its intention to participate in the mission with the provision of a dedicated launch and of additional instruments. This has made it possible to enhance the scientific and application-orientated value of the mission and to optimise the spacecraft design. This article reviews the new joint ESA-NASA Aristoteles mission, as well as the status of the system definition and of the associated technological pre-development activities.

* Applications and Research Involving Space Techniques to Observe The Earth's fields from Low Earth orbiting Satellites.

The Aristoteles objectives

There is now mounting concern that our planet is undergoing rapid changes and that these changes may soon have a significant impact on our daily lives. To fully understand these changes, we must improve our knowledge of the dynamic processes governing the Earth as one global system, with the solid-Earth, cryosphere (ice), hydrosphere (oceans), atmosphere and biosphere as constituents.

An essential pre-requisite for understanding the structure, the dynamics and the evolution of our planet is an accurate knowledge of its potential fields of forces: the gravitational field and the magnetic field. Because of their dependence on the mass properties, distribution and motion inside the Earth, these fields vary spatially and temporally. They have been determined until now in a general way, but not in sufficient detail and, more importantly, not homogeneously on a global scale (Fig. 1). In particular, the geoid, which is the surface of constant gravity potential at mean sea level, is generally not known to better than about a metre or even worse in areas with little gravity information, like Asia and South America.

At least five areas in Earth sciences and applications will benefit enormously from the vast improvement in our knowledge of the geopotential fields that will be brought about by Aristoteles:
- geodynamics
- oceanography
- climate and sea-level studies
- geodesy, orbital mechanics and navigation
- atmospheric modelling.

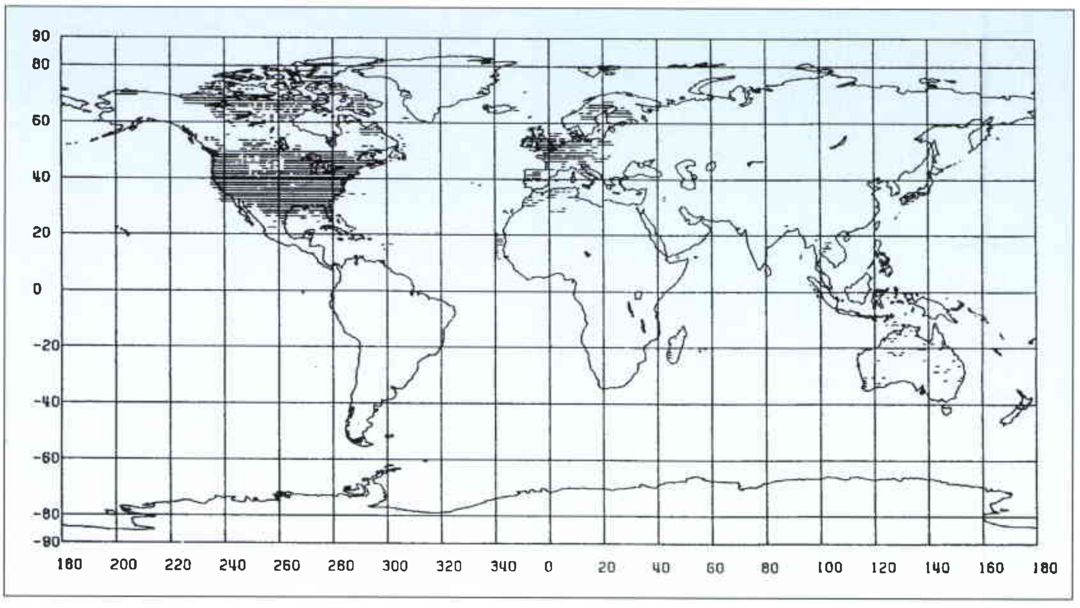


Figure 1. Land areas for which gravity measurements have an accuracy of 2 milliGal or better (1° x 1° blocks)

Geodynamics

A detailed knowledge of the geopotential fields is vital to the study of the structure and dynamics of every single layer of the solid-Earth, starting from the crust and the lithosphere, down through the mantle to the core, deep in the Earth's interior.

In the crust, mechanical and thermodynamic processes and geological features are reflected by variations in both the gravitational and magnetic fields. These variations, called 'gravity and magnetic anomalies', will be precisely determined using Aristoteles.

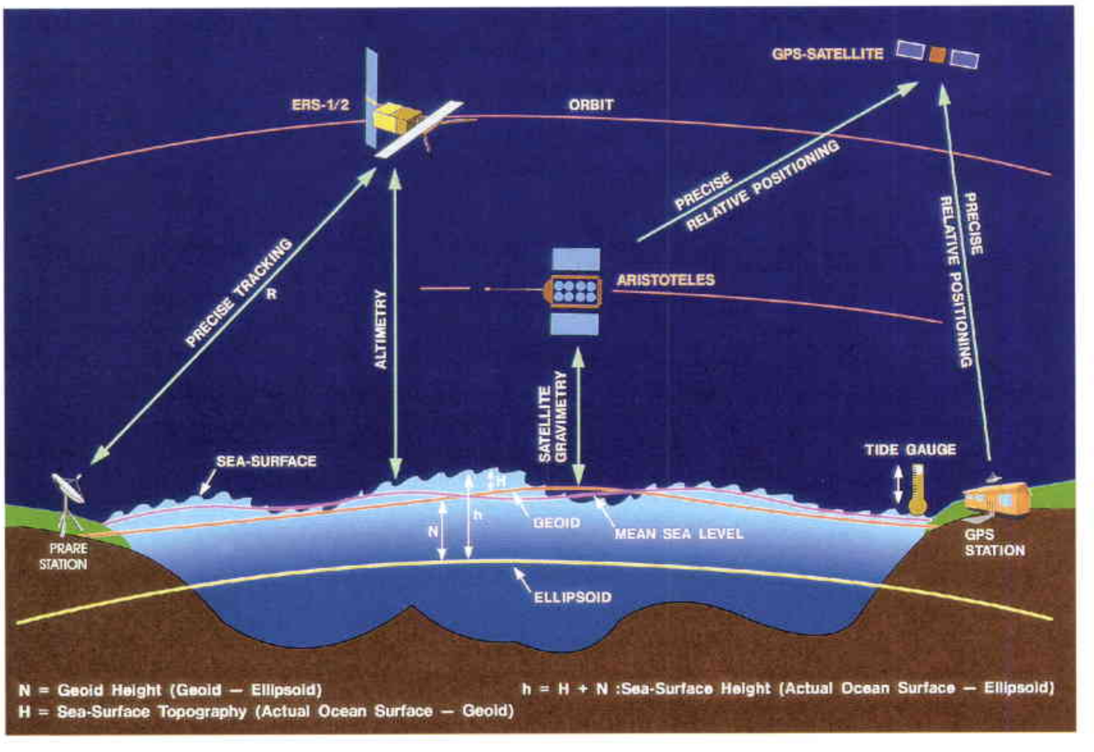


Figure 2. The precise geoid provided by Aristoteles is essential for exploiting space altimetry data and obtaining the sea-surface topography, from which improved models of the ocean circulation can be derived. It is also required for correctly interpreting various measurements of sea-level, such as those given by tide gauges. The figure also illustrates the principle of precise orbit determination via relative positioning with GPS

Study of the structure of the oceanic lithosphere and its interaction with the asthenosphere, as well as that of the continental lithosphere and the forces that drive continental tectonics, requires much-improved geopotential models. This knowledge would also be extremely precious for deriving earthquake dynamic models and for resources prospecting.

The properties of the Earth's mantle, the liquid and the solid core and their mutual interactions can be investigated in practice only by examining their effects on the geopotential fields. In particular, the long-term variations in the magnetic field yield valuable information about the dynamics deep in the Earth's interior.

Oceanography

A better knowledge of global ocean circulation is the key to a better understanding of ocean transport processes, such as the movement of plankton, polluted water or heat. In particular, understanding the transport of heat into deep water is essential for climate-change studies.

The very accurate geoid models provided by Aristoteles, in combination with satellite altimetry (e.g. from ERS-1/2, or the recently launched French–US Topex/Poseidon), will facilitate continuous measurement of the ocean circulation on a global basis. Figure 2 shows how the topography of the sea surface, needed for ocean-circulation studies, can be precisely determined by relating sea-surface heights to an accurate reference geoid.

Climate and sea-level studies

The mean sea level appears to have risen in the past at a rate of about 15 cm per hundred years. However, rates of between 50 and 170 cm per hundred years have been predicted for the future because of man-made influences. If these higher estimates were to prove correct, the consequences for large areas of the World would be dramatic.

It is, then, essential that a monitoring system be established consisting of altimeter measurements and tide-gauge measurements tied into one unified height reference system with centimetre precision by space positioning. To achieve this, one must have a precise geoid. Improved gravity-field information will also help in discriminating sea-level changes from land subsidence or uplifting.

Variations in the geomagnetic field are physically correlated with the variations in the Earth's rotation rate (i.e. the length of day). These variations are in turn strongly linked to various climatic indices such as global surface warming. New geomagnetic information is sorely needed in order to be able to study these phenomena in detail (Fig. 3).

Geodesy, orbital mechanics and navigation

Precise gravity models are needed for a number of geodetic applications, such as determining accurate levelled heights for civil constructions, mapping and exploration. Geometric heights can nowadays be obtained efficiently from space positioning, e.g. using the Global Positioning System (GPS). To convert them into levelled heights again requires a precise knowledge of the geoid, as shown in Figure 4.

A number of space missions, particularly those carrying altimeters, require precise orbit determination at the centimetre level. A poor knowledge of the gravity field is presently the main limiting factor, and one which the Aristoteles data will remove.

In terms of navigation, better magnetic-field models will provide new, updated magnetic charts. In addition, better gravity-field knowledge will improve the performance of inertial navigation systems.

Atmospheric modelling

The possibility of accurate modelling of the atmospheric density at different altitudes represents a byproduct of the Aristoteles gradiometer data that is of direct interest to atmospheric researchers. In addition, improved models of the external magnetic field due, for example, to the ionospheric currents, will help in determining the coupling of energy from interplanetary space to the atmosphere through the magnetosphere. Atmospheric studies will also benefit from the analysis of the GPS microwave signals received by Aristoteles through various layers of the Earth's atmosphere (GPS occultation analysis). This analysis will provide important information on such key atmospheric parameters as pressure and temperature.

Mission requirements

To achieve the objectives outlined above, global and regional models of the gravity field and of the geoid have to be accurate to 5 milliGal* and 15 cm, respectively, with a spatial resolution of 100 km. The addition of the NASA-provided GPS receiver to the main Aristoteles instrument, the gravity gradiometer, leads us to expect even better accuracies of about 1 milliGal for the gravity field and 3 cm for the geoid, thanks to the perfect complementarity of the two instruments. In fact, gravity anomalies of long wavelength (more than 1500 km) are well reconstituted from GPS tracking data, whereas the gravity gradiometer allows the gravity field to be derived at shorter wavelengths.

* 1 milliGal = 10^{-5} m/s^2 $\simeq$ 1 μg
(one millionth of the value of gravity at the ground).

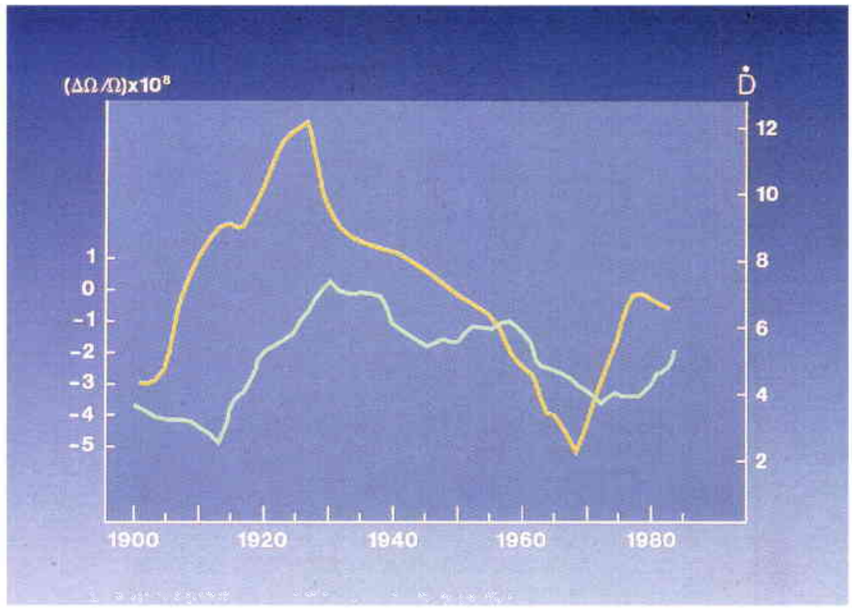


Figure 3. Long-term variations in the main geomagnetic field (Ḋ solid line) are physically correlated with the relative changes in the Earth's rotation rate (ΔΩ/Ω, dotted line), which are linked in turn with various climatic factors.

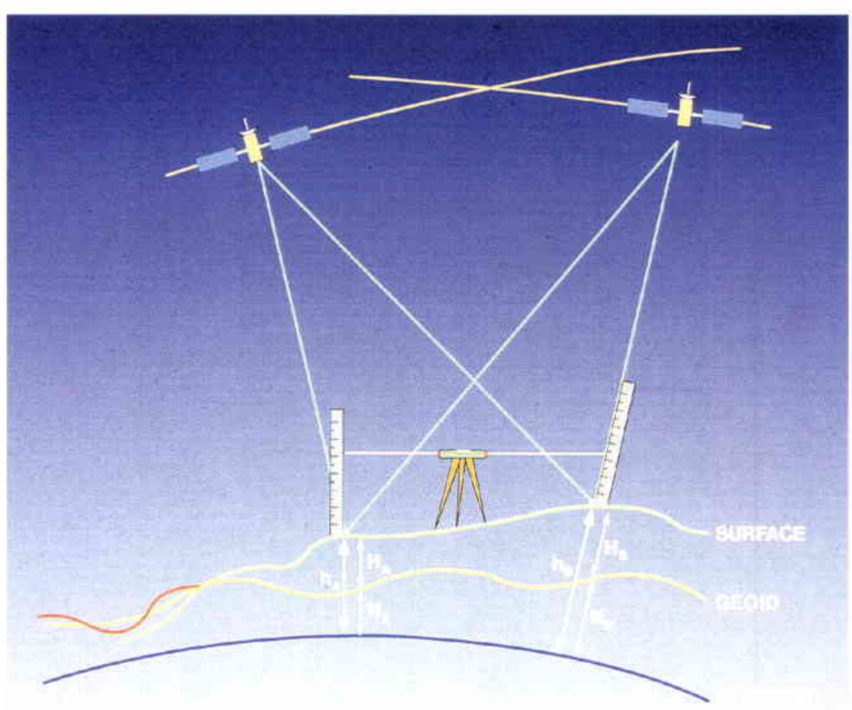


Figure 4. A practical application of the precise geoid: levelled heights (H) are obtained from geometric heights (h), determined using GPS by subtracting geoid heights (N) rather than by laborious spirit levelling.

Geomagnetic studies require in-orbit measurement of the three components of the magnetic flux density with an accuracy of 5 nanoTesla. For comparison, the field on the ground is between 60 000 nT at the geomagnetic poles and 30 000 nT at the geomagnetic equator. The final accuracy expected from the Aristoteles magnetometer instrumentation is about 3 nT per component.

Mission profile and operations

Thanks to the provision of a dedicated launcher, the Aristoteles mission profile has been optimised so as to achieve all of the scientific objectives. The required global coverage is obtained by operating in a near-polar circular orbit, which will be quasi Sun-synchronous during the first nine months and thereafter will be closer to a perfect polar orbit.

Following launch, the first two months of the mission at 400 km altitude will be dedicated to the checking-out of the spacecraft subsystems and to the calibration of the instruments. The first fully operational phase, lasting six and a half months, will take place at the very low altitude of 200 km in order to measure both gravitational and magnetic anomalies originating in the Earth's lithosphere with good sensitivity. The altitude of 200 km represents a compromise, since the amplitude of the higher harmonics of both fields decreases dramatically with increasing altitude, while on the other hand the rate of orbital decay increases rapidly with decreasing altitude (Fig. 5).

The orbit decay rate is determined by the air density, which in turn depends on solar activity. A launch in a period of low solar activity is therefore preferable in order to minimise the fuel needed for orbit maintenance. The launch of Aristoteles is foreseen to take place in 1998, close to the next solar minimum.

The last 15 days at 200 km altitude will be preceded by a change of inclination to about 92°, so as to improve the coverage over the poles and to achieve during the subsequent phase the rapid sampling of all solar times needed to separate diurnal and seasonal effects in geomagnetic studies. The last phase, at an altitude of 480 km, will last at least three years, in order to measure the long-term changes in the geomagnetic field (secular field variation).

The spacecraft's attitude will be such that one axis will be constantly pointing to the centre of the Earth during the mission phase at 200 km altitude. During this and the remaining phases, the necessary Sun-pointing of the solar panels will also have to be ensured.

The mission will be controlled from ESA's European Space Operations Centre (ESOC), in Darmstadt (D), via a dedicated ground station located in Kiruna (S) close to the ERS station. The possibility of using a ground station at Spitzbergen in Norway and another one at Tiksi in the CIS in order to increase the ground coverage is presently being considered.

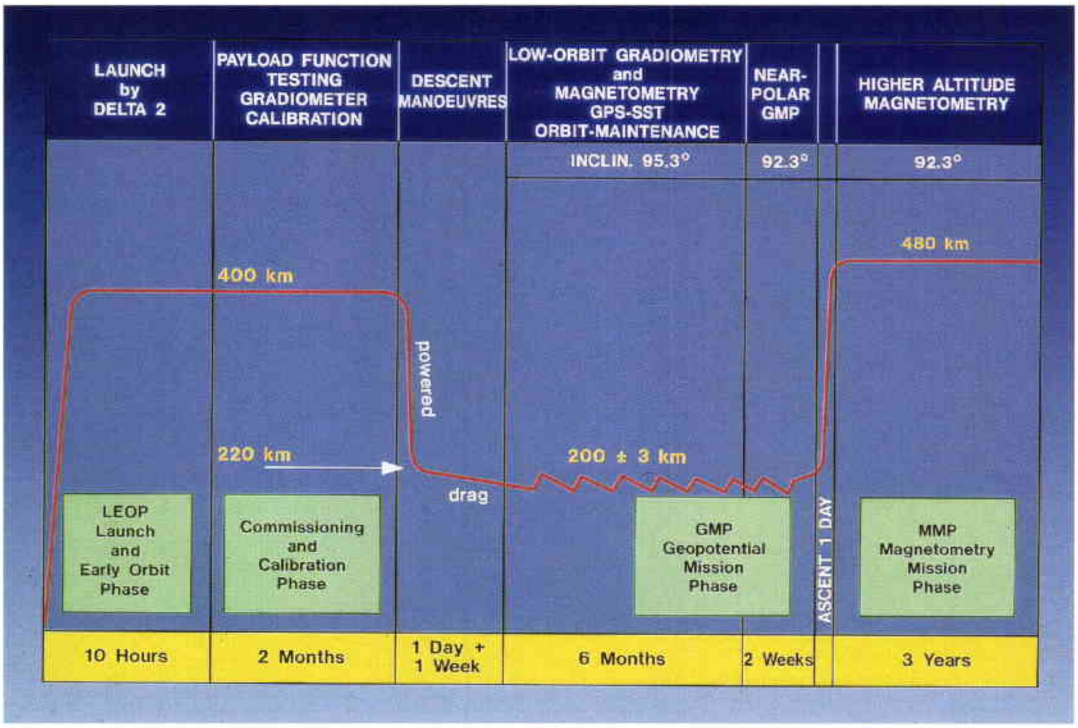


Figure 5. The Aristoteles mission profile consists of a Launch and Early Orbit Phase (LEOP), a Calibration Mission Phase (CMP), a Geopotential Mission Phase (GMP) and a Magnetometry Mission Phase (MMP). The GMP is composed of two sub-phases at different inclinations

The payload

Aristoteles' payload consists of four instruments:

- the gravity gradiometer
- the Global Positioning System (GPS) receiver
- the vector magnetometer
- the scalar magnetometer.

The gravity gradiometer (so-called 'Gradio') will be provided by ESA, and the remaining three instruments will be part of the NASA contribution to the mission. While the magnetometers will be dedicated exclusively to geomagnetic studies, the GPS receiver will play a dual role of gravimetry instrument and of tracking system for the precise positioning of the Aristoteles spacecraft with respect to the Earth.

The gravity gradiometer: principle and realisation

Gradio is certainly the most unusual and complex of the four instruments. Its operating principle can be understood by imagining an ideal experiment in which four free-flying masses are in orbit around the Earth at slightly different positions, e.g. 1 m apart (Fig. 6a). Each mass will then experience a different gravitational force because of the difference in its position in the Earth's gravitational field and will therefore follow a slightly different orbit. From precise observations of the relative motion of these masses, it is then possible to derive information on the structure of the gravitational field.

Such an experiment is not realistic because the masses would soon drift apart and because other perturbing forces like air drag would act differently on each mass. It is, however, possible to enclose each mass in a small chamber fixed in a spacecraft and to measure very precisely the force required to keep the mass exactly in the centre of its chamber (Fig. 6b). The difference between the forces required to hold the masses in a fixed position provides the same knowledge about the local structure of the gravitational field as the ideal experiment described above.

Similarly, Gradio will provide acceleration measurements obtained at different positions within the spacecraft. From these accelerations, after some data processing, it will be possible to recover the local variations in the gravity field or, more precisely, the components of the gravity gradient in the vertical direction and in the direction normal to the orbital plane. These gravity-gradient measurements, collected over a period of more than six months at the very low altitude of 200 km, will enable one to determine the anomalies of the gravity field at medium and short wavelengths, to a spatial resolution of 100 km.

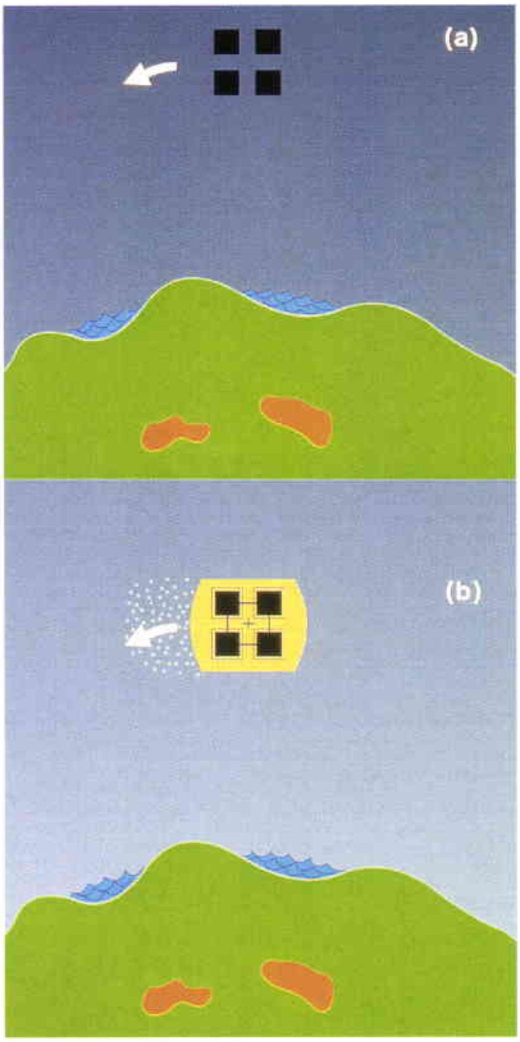


Figure 6. The principle of space gravity gradiometry: (a) test masses follow different orbits because of the local differences in gravitational attraction; (b) if the masses are constrained to be fixed in a spacecraft, the difference in the forces that must be applied to the masses provides information on the gravity field

The accelerations will be detected by means of four accelerometers located at the corners of a square, the sides of which are 1 m long (Fig. 7). Each accelerometer will contain a proof mass, which will be electrostatically controlled so as to remain at the centre of a small chamber fixed to the spacecraft. The 4 cm x 4 cm x1 cm proof mass, made of platinum-rhodium alloy, will weigh 320 g. The stability of the position and alignment of each accelerometer will be ensured by the use of a highly stable mounting plate thermally insulated from the rest of the spacecraft (Fig. 8).

Each accelerometer will measure the accelerations along the three orthogonal axes, one axis being less sensitive than the others so that it can cope with the relatively strong acceleration in the flight direction caused by the aerodynamic drag acting on

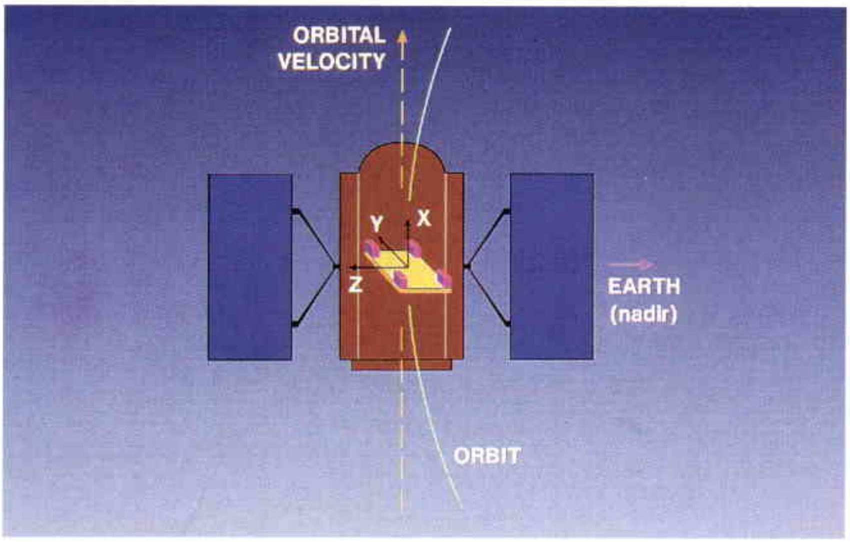


Figure 7. Schematic of the Aristoteles satellite, showing the gravity gradiometer instrument at its centre and the four accelerometers

the spacecraft. Only the two sensitive axes will directly contribute to the gravity-gradient measurements.

The extreme sensitivity of 0.01 Eötvös (1 Eötvös = 10^{-9} s^{-2}; i.e. difference of 10^{-9} ms^{-2} acceleration per metre) required for the gravity-gradient measurements demands an extraordinary sensitivity of less than 1 pico-g (one millionth of a millionth of the value of gravity on ground) from each accelerometer. Moreover, it imposes the use of on-board calibration mechanisms to generate three reference forces with perfectly known characteristics, and the use of very precise signal-processing units.

The GPS tracking system

The anomalies in the Earth's gravitational field produce perturbations in the orbit of a satellite, particularly one operating at low altitude. These perturbations can be sensed with tracking systems that measure the distance or velocity of the satellite along the line of sight to the tracker. Satellite tracking from the ground has therefore been used to map the gravitational field since the very early days of space exploration. Indeed, one of the first discoveries in the late fifties was the existence of a small difference between the northern and southern hemispheres, making the Earth slightly pear-shaped.

Aristoteles can be tracked continuously and accurately as it circles the Earth from the satellites of the US Global Positioning System (GPS). By the time Aristoteles flies, more than twenty GPS satellites will be operational, allowing its on-board GPS receiver to acquire and decode the signals emitted from at least six of them simultaneously at any time. The data from the on-board GPS receiver will be supplemented by data gathered from a worldwide ground network of GPS receivers, already partially deployed for other geodetic research activities. The tracking data from this network will allow the use of a differential technique for the precise orbit determination. Using measurements of the phase of the GPS carrier signals accurate to a few millimetres, it will be possible to determine the relative positions of the on-board and ground receivers with an accuracy of a few centimetres.

The analysis of the tracking data provides information about the components of the gravitational field at long and medium wavelengths which, combined with the components obtained from Gradio, will enable one to reconstitute the field to the expected accuracy of about 1 milliGal over the complete range of wavelengths.

In addition to the use of the tracking data for determining the gravity field, an accurate knowledge of the spacecraft orbital position

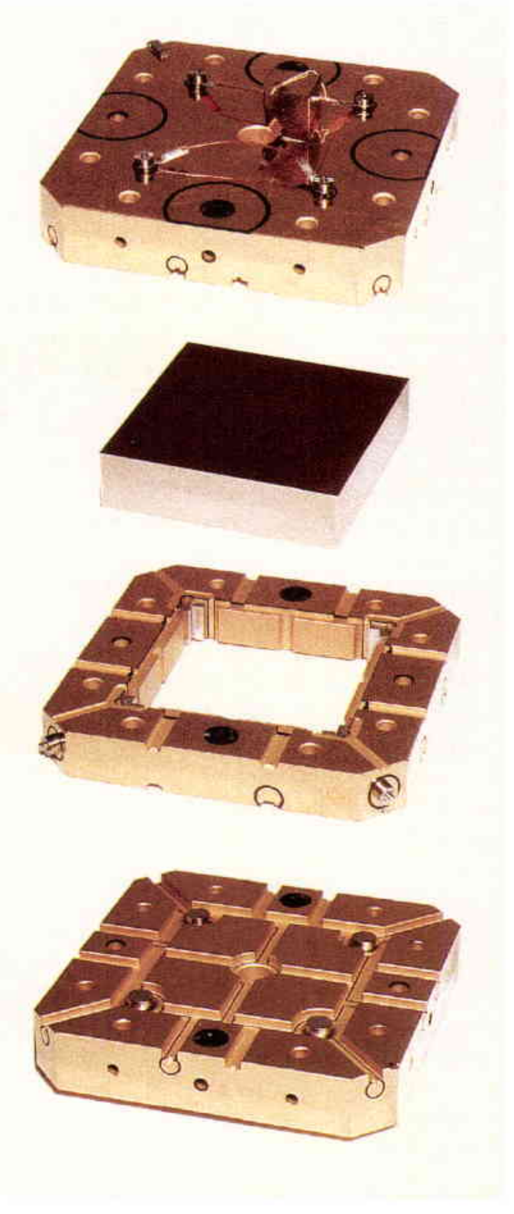


Figure 8. Main mechanical elements of the accelerometer development model: from top to bottom, the upper electrode plate, the proof mass, the electrode ring and the lower electrode plate. The electrode plates are made by ultrasonic cutting of gold-coated ultra-stable glass

will be derived for processing both the gradiometer and the magnetometer data, and for planning the sequence of orbit maintenance manoeuvres. These are required to keep the spacecraft at an altitude of about 200 km despite the rapid decay caused by the high aerodynamic drag.

The magnetometer instrumentation

The magnetometer instrumentation consists of a scalar magnetometer, to measure the total magnetic field strength, and a vector magnetometer, which provides the components of the field in three directions (vertical, along and across the orbit). Both magnetometers will be mounted at the tip of a 4.5 m boom in order to separate them from perturbing magnetic sources on the satellite. An optical Attitude Transfer System (ATS) will relate the orientation of the vector magnetometer with that of the star-trackers. In this way the vector-magnetometer measurements will be referred to a reference frame given by the observed stars with an accuracy of about 10 arcsec.

The scalar magnetometer has an intrinsically high measurement stability and is therefore mainly used to calibrate the vector magnetometer, which on the contrary is subject to long-term drift. The reason for this stability lies in its operating principle, which depends on atomic-scale phenomena. In its two sensor heads, helium atoms are optically excited, so inducing a bulk magnetic moment in the gas. The precession of the magnetic moment about the magnetic field provides a signal at a frequency in a very well known relationship with the field magnitude. By measuring this frequency, it will be possible to achieve a final accuracy better than the 1 nanoTesla already obtained with other similar instruments flown successfully on planetary missions.

The operation of the vector magnetometer is based on the flux-gate technique, which involves the saturation of ferromagnetic material by an alternating magnetic drive field. This magnetometer is therefore composed of three sensors, one for each measurement axis and each of them containing a ferromagnetic core. Its accuracy is limited by slow parameter changes, and to reach a final accuracy of a few nanoTesla per component it must be calibrated using the scalar measurements. Such calibration has already been successfully demonstrated by the Magsat geomagnetic mission, flown by NASA in the late seventies (Fig. 9).

The spacecraft design

The design of the Aristoteles spacecraft has been strongly influenced by the mission profile and by the accommodation needs of the payload, particularly the gradiometer.

The frontal area in the flight direction has been minimised to reduce the air drag and therefore the orbit decay rate. This has led to a rather slender satellite configuration. Orbit-raising manoeuvres are anyway foreseen to take place about every 36 h when at 200 km altitude. The hydrazine fuel necessary for these manoeuvres and for the orbit changes between mission phases will constitute almost half of the spacecraft's 2300 kg mass at launch (Fig. 10).

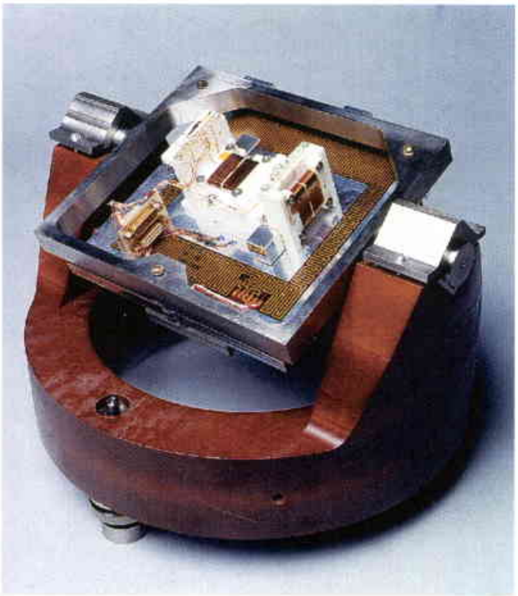


Figure 9. Prototype of the vector magnetometer sensor head

The fuel will be contained in eight tanks symmetrically located around the gradiometer, which occupies the spacecraft centre position and has its plane perpendicular to the flight direction. The configuration of the tanks and of the other units has been optimised to avoid changes in the position of the spacecraft's centre of mass due to fuel depletion and sloshing, which would be detrimental to Gradio's operation.

The combination of low altitude and a polar orbit limits the visibility of the spacecraft from the ground station to a few minutes per orbit, with long gaps between contact periods. The data collected on-board will therefore be stored in a 300 Mbit solid-state memory and then transmitted to the ground during contact periods. During non-contact periods, the spacecraft will autonomously perform orbit manoeuvres and subsystem reconfigurations in the event of a failure.

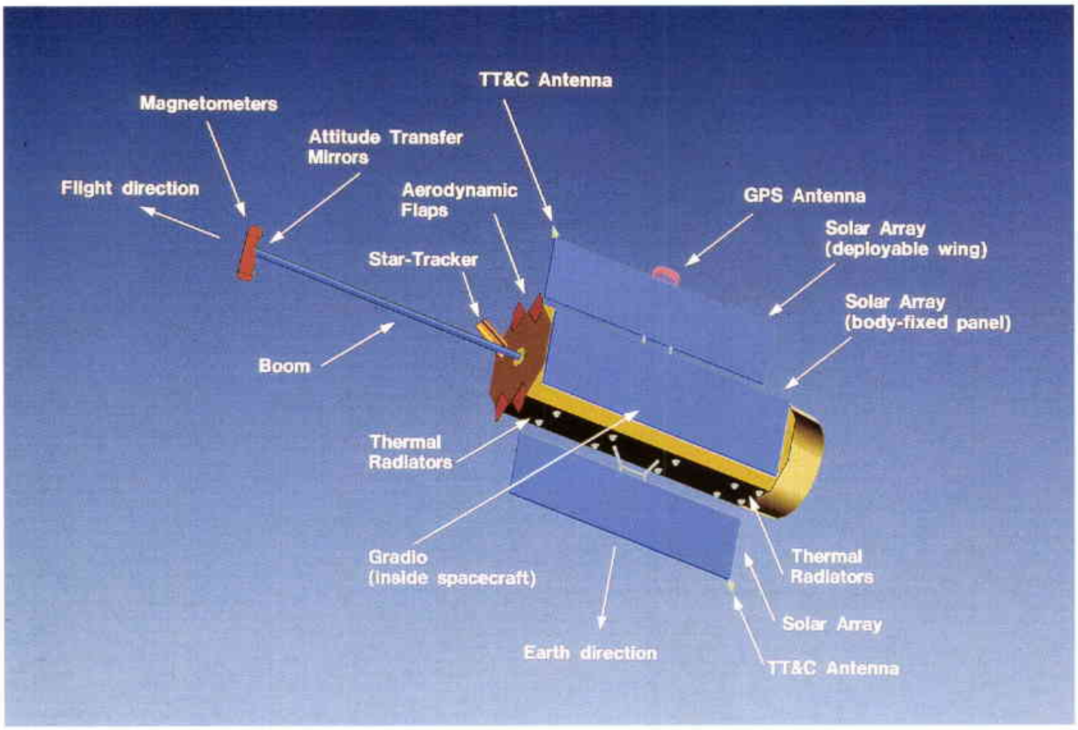


Figure 10. Exterior of the Aristoteles spacecraft

The satellite's attitude will be controlled extremely smoothly by means of small reaction wheels and magnetic torquers, to keep the centrifugal accelerations on the accelerometer proof masses to a minimum. Small aerodynamic flaps mounted on the satellite and commanded on the basis of the accelerometer measurements will reduce the dynamic perturbations produced by changes in air density. In addition, all flexible parts like solar arrays and booms will be made quite stiff to prevent the build-up of undesirable vibrations.

For the same reason, the solar arrays will not rotate, but will be fixed with respect to the main spacecraft body. The position of the solar array, composed of two deployable wings and a body-mounted panel, with the panel edges in the flight direction, will minimise the aerodynamic drag. To achieve the required field of view, the TT&C and GPS antennas will be mounted at the edges of the two solar-array wings.

Despite the accommodation of the magnetometers at the end of a long boom, accurate magnetic measurements still demand strict control over the magnetic sources on-board the spacecraft. The most perturbing units, such as the nickel-cadmium batteries, will in any case be located as far as possible from the magnetometers. The field produced by the magnetic torquers used for attitude control will be accurately monitored and then removed in the data-reduction phase.

The main spacecraft parameters are summarised in the accompanying table.

Table 1. Main spacecraft parameters

Mass at launch	2300 kg
Fuel mass	960 kg
Length of main body (without boom)	4.5 m
Cross-sectional area	2.2 m^2
Solar-array power (end of life)	1.1 kW
Solar-array area	12.8 m^2
Data-storage capability	300 Mbit
Telemetry data rate	1 Mbit/s
Telecommand data rate	4 kbit/s

Programme preparatory activities

A solid-Earth programme was included in ESA's Long-Term Space Plan presented to the ESA Council Meeting at Ministerial Level in Rome in 1985, and was further endorsed at the subsequent Ministerial Conference in The Hague in 1987 as a key element of the Agency's Earth-observation activities. It was therefore shortly after that that the preparatory activities began, consisting primarily of system studies and technological pre-development activities.

Following these so-called 'Phase-A' studies, which were performed considering a fully European scenario, a new system study has been carried out by a European industrial consortium led by Alenia Spazio of Italy (from June 1991 until April 1992) to take into account the planned participation by NASA through the provision of a dedicated Delta-II launcher, a GPS receiver and the magnetometer instrumentation. The possibility of using a dedicated launcher has allowed optimisation of the mission profile so as to achieve a more ambitious set of scientific objectives. This in turn has led to a thorough revision of the satellite configuration and of its interfaces with the launcher. Technical and programmatic discussions with NASA, which started in 1986, have continued in parallel with the system studies.

The mission has been re-defined in close collaboration with the scientific community. Indeed, at a joint ESA-NASA Workshop held in Anacapri (I) in September 1991, a large representation of this international community expressed its strong support for the new, enhanced scientific objectives and for the proposed implementation of the mission. This wide support has also been expressed at several other scientific events, including the General Assemblies of the International Union of Geodesy and Geophysics (IUGG) held in Vancouver in 1987 and in Vienna in 1991.

The technological pre-development activities have concentrated mainly on the two key components of the gravity gradiometer: the accelerometer and the calibration device. The accelerometer studies, initiated in 1988 by Onera (F), have led to the manufacture and extensive testing of several laboratory models of the accelerometers and finally, in 1992, to the production of the first development model, which is expected to be very similar to the final flight model. This development has made use of the most advanced technologies in high-precision machining and in space electronics, such as the ultrasonic micro-machining of ceramic glass and the production of ultra-stable thin-film hybrid circuits.

In parallel, a considerable effort has been put into the development of a facility for testing the accelerometers under normal gravity conditions. This has resulted in the manufacture of a dual-stage vibration-isolation system, which consists of a pendulum platform controlled in a closed-loop fashion on the basis of the readings from very sensitive inclinometers and capacitive sensors. This test bench has allowed very impressive results to be achieved during the testing of two accelerometer laboratory models in differential mode. Despite the comparatively high level of environmental noise and the presence of the full 1 g gravitational acceleration on one axis, the residual noise at the output of the accelerometers has been found to be well below 1 nano-g, i.e. less than one billionth of gravity on the ground.

These results, combined with extensive theoretical analyses and computer-based simulations to extrapolate the final performance in space, have confirmed that the main design requirements for the accelerometers, such as sensitivity, coupling between axes and output stability, can indeed be achieved.

The pre-development of the calibration device at TNO-TPD (NL) has recently led to the production and successful testing of laboratory hardware. Each device consists essentially of a mass vibrating at a very well known frequency and producing a harmonic force in a direction known with 1 arcsec accuracy. The design of the mechanical parts and of the associated position-sensing and control electronics represents a new and technologically advanced development.

On the US side, instrument studies are in progress concerning the GPS receiver and the magnetometer instrumentation, including the ATS. While for the magnetometers only the adaptation of existing space hardware is required, the final choice of a GPS receiver design is still open. The alternatives are to fly a modified version of the GPS receiver that is presently being used on the NASA–CNES altimetry mission Topex-Poseidon, or to develop a space version of a new high-accuracy receiver developed by NASA for geodetic applications.

Conclusion

The importance of the Aristoteles mission to the advancement of a whole range of geosciences and their applications is now well established and internationally recognised. In particular, its impact on our understanding of global dynamics and of basic environmental phenomena such as those that govern the seismicity, sea-level variations and climatic evolution of our planet, has been strongly emphasised by the World's geoscientists.

The technical preparation of the mission is well advanced and the feasibility of the main instruments has been demonstrated. NASA's participation is expected to contribute to the achievement of all of the objectives of this mission, which represents a quantum leap forward in our understanding of our planet.

ERS-1 – An Earth Observer that Exactly Follows Its Chosen Path

M. Rosengren
Orbit Attitude Division, European Space Operations Centre (ESOC), Darmstadt, Germany

ERS-1, Europe's first Earth-observation satellite to be based on active microwave instrumentation (i.e. radars), was put into orbit on 17 July 1991 by an Ariane launch vehicle. This article describes the high-accuracy orbit design and control that has been a highlight of the satellite's first year of operations.

The polar orbit

The low polar orbit has been a popular choice from the outset of the satellite era and such an orbit with an altitude of about 800 km has also been selected for ERS-1. The advantage of a polar orbit is that the combination of the Earth's rotation about its axis and the spacecraft's orbital motion around the Earth results in very complete scanning of the globe (Fig. 1). The duration of one revolution around the Earth for a spacecraft in a low orbit is typically in the order of 1.5 to 2 h. The rotational phase of the Earth therefore changes by about 20° to 30° between two consecutive spacecraft orbits. The ground track for successive crossings of the equatorial plane from south to north will shift by some 2500–3400 km towards the west. For other latitudes, the westward shift will be less pronounced.

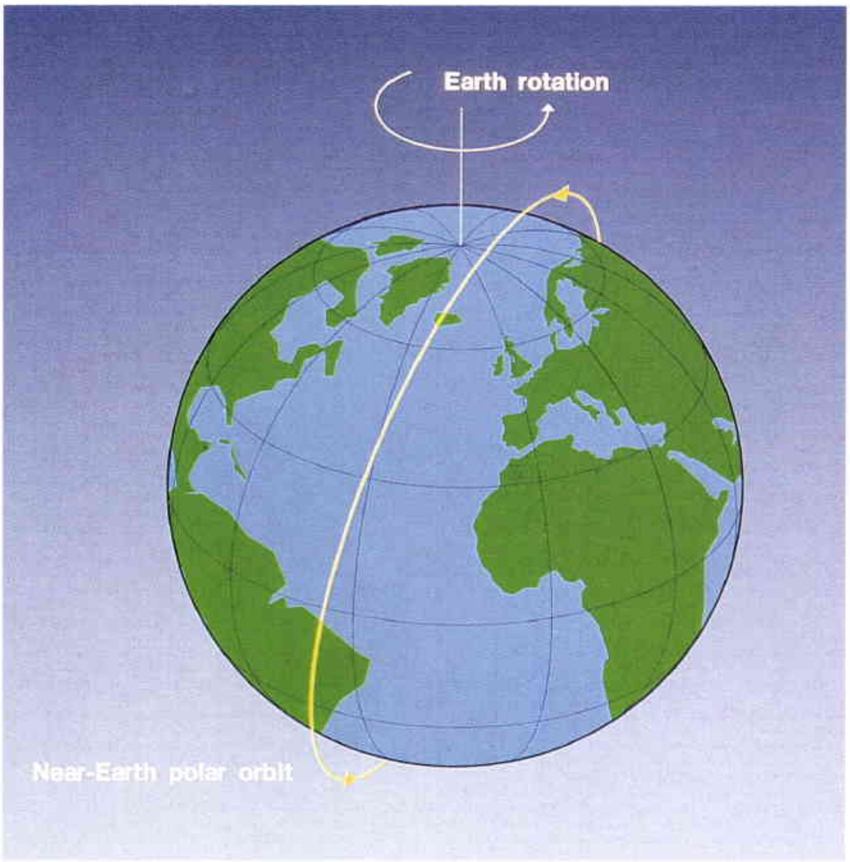


Figure 1. The orbital period for a near-Earth spacecraft is typically 1.5 to 2 hours (1 h 40 min for ERS-1)

While a geostationary orbit allows continuous observation of almost half of the Earth's surface from a great distance (e.g. Meteosat, at an an altitude of 36 000 km), the low polar orbit allows much closer inspection of any point on the Earth's surface. At an altitude of 800 km, for example, the polar-orbiting spacecraft is still above the horizon at a distance of 3000 km from the sub-satellite point. For any point on the Earth, it is therefore assured that the spacecraft will rise over the horizon at least once every 12 h, travelling alternately from south to north and from north to south during successive appearances.

The further from the equator and the closer to one of the poles one is situated, the more often the spacecraft will rise above the horizon. The extreme cases are the poles themselves, where the spacecraft will be visible for a time during every revolution. The main ground station for ERS-1 has been built close to Kiruna in Sweden, as this is sufficiently far north to have a visibility period for most of the orbits, and sufficiently close to civilisation to avoid the difficulties and hardships of more remote locations.

The ERS-1 spacecraft

The ERS-1 spacecraft was described in considerable detail in ESA Bulletin No. 65, but for completeness those features of the spacecraft that play a role in the orbit design will be recounted here.

The spacecraft's layout is shown in Figure 2. The Radar Altimeter (RA) and the Along-

Track Scanning Radiometer and Microwave Sounder (ATSR-M) are mounted on the −Z face of the spacecraft. The ATSR-M consists of two instruments, an Infrared Radiometer (IRR) and a Microwave Radiometer (MWR). The fields of view of the RA and the MWR are in the −Z axis direction. The IRR scans with the help of a rotating mirror in a cone from the −Z axis direction to a direction offset towards the −Y axis. The attitude of ERS-1 is maintained such that its −Z axis, and therefore the RA and the MWR, are directed towards the subsatellite point on the Earth's surface (nadir). The −Y face of the spacecraft is in the 'forward' direction, 'forward' being the direction of motion of the subsatellite point relative to the Earth's surface. This attitude control mode is called the 'Yaw Steering Mode'. To maintain this pointing, the spacecraft rotates about its +X axis, making one complete rotation during one spacecraft orbit.

The Synthetic Aperture Radar (SAR) antenna has a viewing direction that is offset by about 20° from the −Z axis towards the −X axis. This results in a scanned strip (swath) of width 100 km with centre displaced 300 km to the right of the subsatellite track (Fig. 3).

The point on the Earth's surface that is observed by the various instruments at a certain moment therefore depends only on the position of the spacecraft (RA and MWR looking vertically down), or on its position and direction of travel (IRR and SAR). To observe the same point several times, therefore, it is necessary for the spacecraft to repeat the same path relative to the Earth. ERS-1's orbital period is close to 100 min, resulting in a shift in longitude of about 25° towards the west between successive orbits. At the equator, this corresponds to a shift of almost 2800 km, which is much more than the width of the strip seen by the SAR instrument. To ensure that the Earth's surface is observed in a regular and systematic manner, a certain repeat pattern has therefore to be maintained.

The repeat pattern

To a first approximation, the spacecraft can be considered to follow a periodic orbit around an Earth that rotates at a constant rate about a fixed spin axis. The spacecraft's motion relative to the Earth in terms of longitude, latitude and altitude between two consecutive orbits will then be a westward shift in longitude of ψP, where ψ is the spin rate of the Earth and P is the orbital period, while longitude and altitude will be identical functions of time t relative to the epoch when

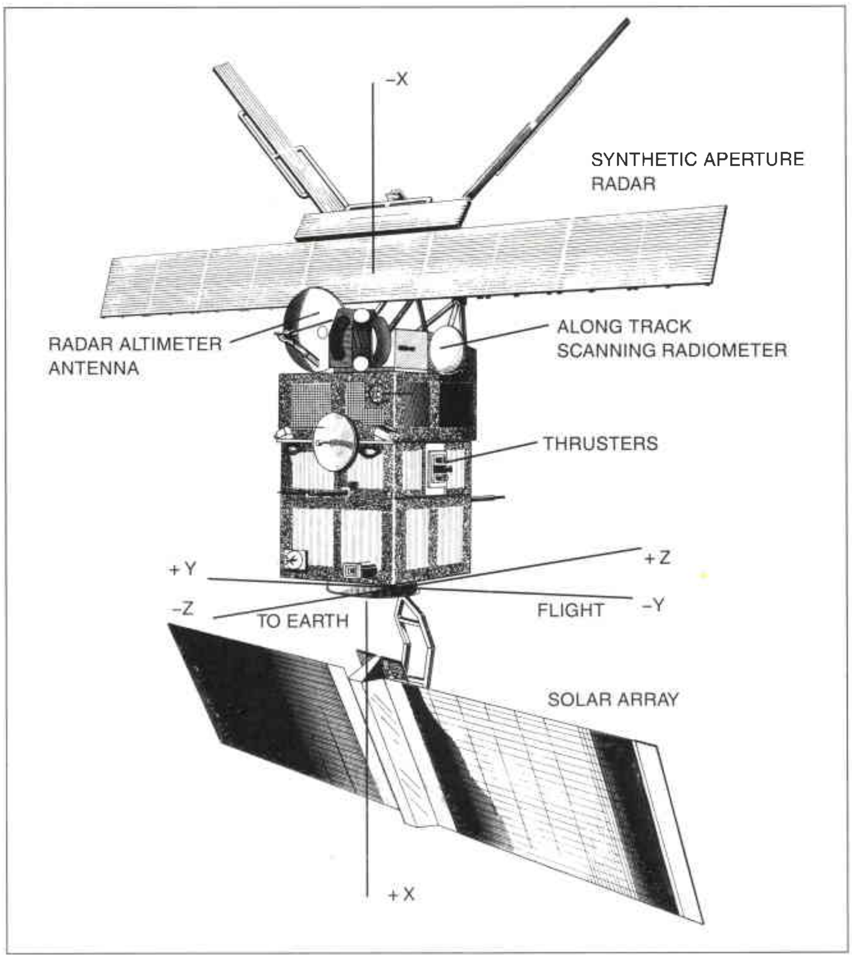


Figure 2. The ERS-1 spacecraft. The −Z axis is kept pointing to the subsatellite point on the Earth's surface, while the −Y axis is 'forward' with respect to the satellite's flight direction. The Synthetic-Aperture Radar (SAR) is offset by 20° from the −Z axis ('side-looking' radar)

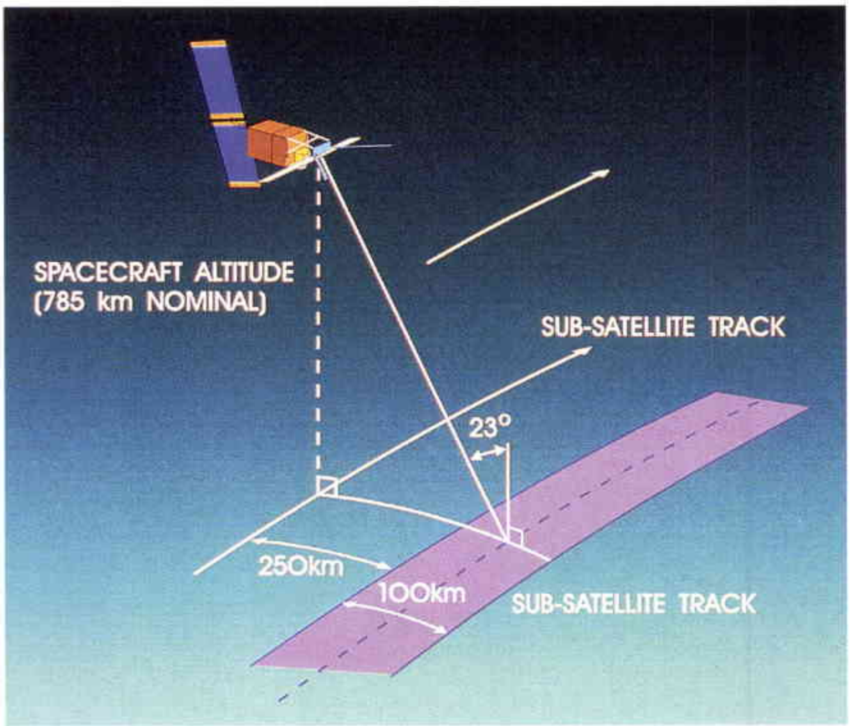


Figure 3. The Synthetic Aperture Radar scans a 100 km wide strip, the centre line of which is displaced 300 km to the right of the subsatellite track ('side-looking' radar)

the spacecraft crossed the Earth's equatorial plane from south to north.

For the spacecraft to be in a periodic orbit relative to the rotating Earth, the craft's orbital period must be a rational fraction *n/m* of the Earth's spin period. After *m* spacecraft orbits and *n* Earth rotations, the spacecraft will then be back over the same point and its motion relative to the Earth will be repeated.

For ERS-1, the orbital periods of 3/43 days and 35/501 days have been selected. This means that the westward shift in longitude between consecutive orbits is 3/43 x 360° or 35/501 x 360°, and that the spacecraft will be back over the same point after 43 or 501 orbits. During these 3 or 35 days there will be 43 or 501 orbits with different ground tracks intersecting the equator at 43 or 501 equidistant points.

The repeat cycle of 3 days results in an adjacent crossing of the equator from south to north 40 000/43 = 930 km further to the east after 14 orbits (1 day−33 min) and 930 km further to the west after 29 orbits (2 days+33 min). A north to south crossing of the equator takes place over the same point after 21.5 orbital revolutions (1.5 days). This is illustrated in Figure 4.

The 35-day repeat cycle results in an adjacent crossing of the equator from south to north 40 000/501 = 80 km further to the east after 229 orbits (16 days−3 min) and 80 km further to the west after 272 orbits (19 days+3 min). A north to south equatorial crossing over the same point thus occurs after 250.5 orbital revolutions (17.5 days). This is illustrated in Figure 5.

Given that the strip covered by the SAR instrument is 100 km wide (Fig. 3), it is clear from Figure 5 that for a repeat cycle of 35 days the strips generated by two orbits separated by 229 orbits and separated by 272 orbits overlap. Complete coverage of the Earth's surface is thereby obtained. With a 3 day repeat orbit, only a part of the Earth's surface can be imaged by the SAR.

The precession of the orbital plane

The above discussion was based on the assumption that the spacecraft orbit is periodic relative to inertial space. However, this is not even approximately true if a longer time span is considered. The dramatic deviation from such a model for ERS-1's almost circular orbit is due to the orbital plane's rotation about the Earth's spin axis. This phenomenon, known as 'precession' (Fig. 6), is due to the fact that the flattening, or 'oblateness', of the Earth (Fig. 7) results in a gravitational force that is not absolutely parallel to the line from the spacecraft to the

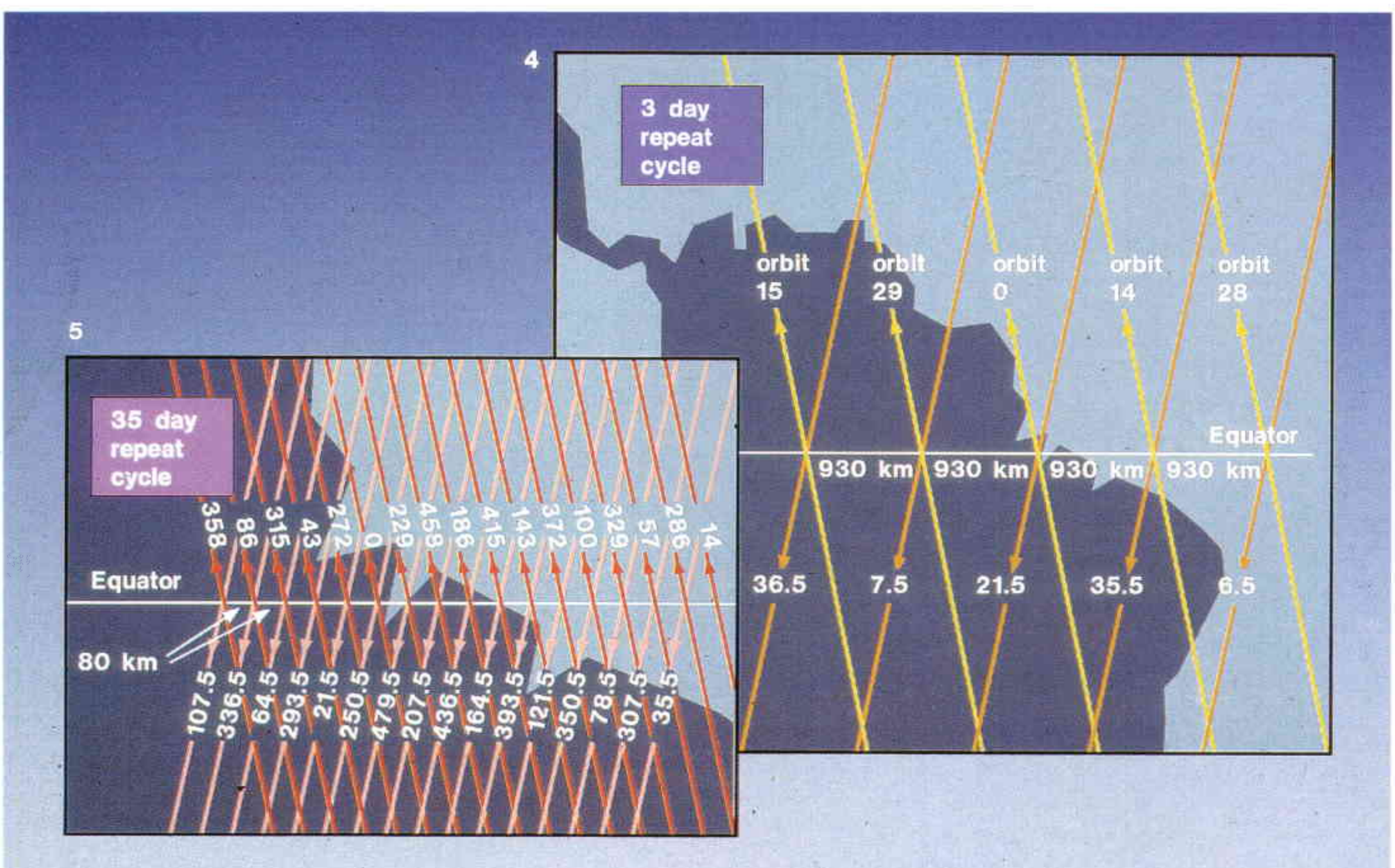


Figure 4. For a 3 day repeat cycle, neighbouring crossings occur of the equator after 14 orbits (1 day−33 min) and 29 orbits (2 days+33 min). After 21.5 orbits there is an equator crossing over the same point in the other direction

Figure 5. For a 35 day repeat cycle, neighbouring crossings at the equator occur after 229 orbits (16 days−3 min) and after 272 orbits (19 days+3 min). After 250.5 orbits there is an equator crossing over the same point in the other direction

Earth's centre, but also has a certain 'out-of-plane' component. It was already shown by Newton that if the Earth is assumed to be a homogenous ellipsoid that is symmetrical relative to the north/south axis, it follows that the orbital plane of a satellite will precess. He used this theory to compute the Earth's oblateness from the observed precession of the orbital plane of the Moon.

ERS-1's orbital parameters have been chosen such that the rate of precession is equal to the mean angular rate of the Earth in its orbit around the Sun. Such an orbit is called 'Sun-synchronous'. Although the plane of the heliocentric orbit of the Earth is inclined by 23.4° to the equatorial plane of the Earth and the angular rate of the Earth in its orbit around the Sun varies by about ±3.5% over a period of a year, the yearly variations in the declination of the Sun relative to the orbital plane of ERS-1 will only vary from 17° at the beginning of June to 27° at the beginning of February (Fig. 8).

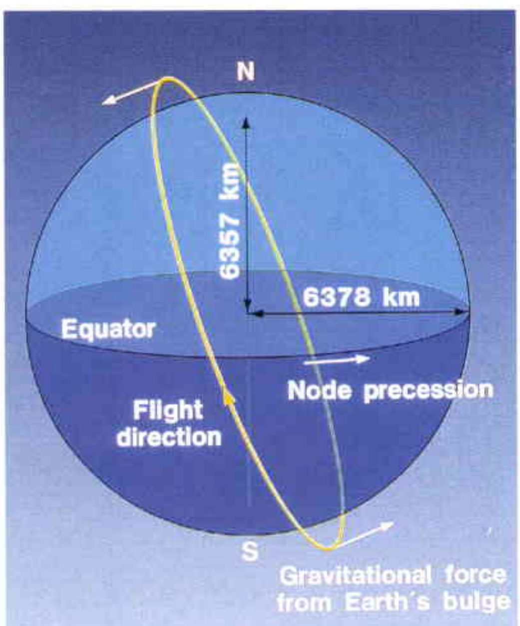


Figure 7. Flattening or 'oblateness' of the Earth, with the globe's equatorial radius 21 km greater than its polar radius

For Earth-observation satellites using optical instruments, like the French Spot satellite, the Sun-synchronisation has the advantage that the lighting conditions for the surface being overflown remain comparatively constant. For ERS-1, which carries only active microwave instruments (radars), the advantage of the Sun-synchronous orbit is that the spacecraft's solar panels need only be rotated about one axis (the spacecraft's Z-axis, which is approximately aligned with the orbital pole) to maintain pointing to within 5° of the Sun's direction.

The period *P* discussed above has to be interpreted as the 'nodal period', i.e. the time between two consecutive crossings of the equatorial plane from south to north, and the spin rate ψ must be interpreted as the 'spin rate of the Earth relative to the precessing orbital plane'. As the usual day of 86 400 sec is the 'mean solar day', i.e. the apparent spin period of the Earth with the Sun as reference, one revolution in 86 400 sec is just the spin rate ψ that applies for a Sun-synchronous orbit.

Other perturbations caused by the Earth

The precession of the orbital plane will not be the only significant orbital perturbation caused by the Earth's oblateness. There will always be periodic perturbations repeating each orbital revolution. In addition, there will generally be a cumulative deformation of the shape of the orbit.

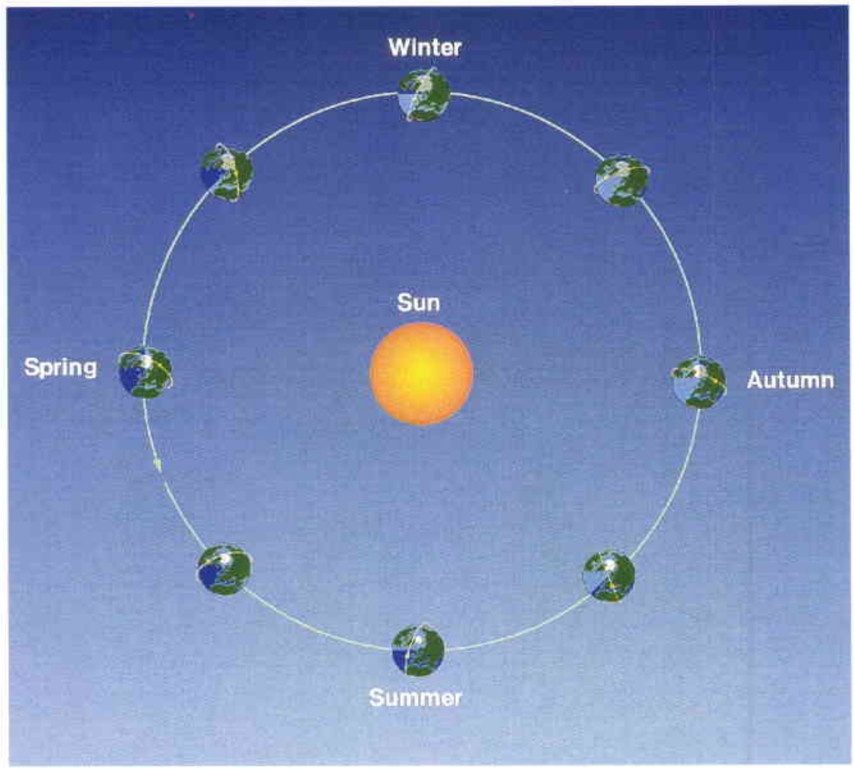


Figure 6. Precession of ERS-1's orbital plane is synchronous with the Earth's motion around the Sun

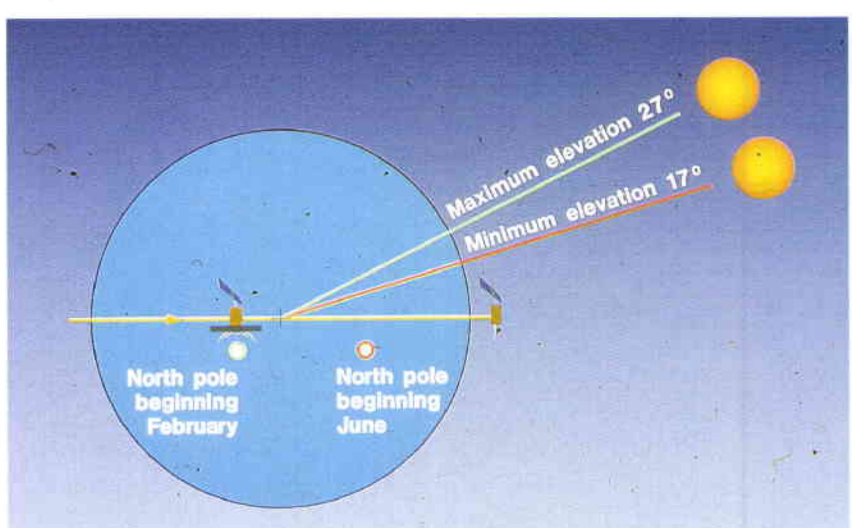


Figure 8. Variation in the Sun's elevation relative to the orbital plane of ERS-1

These two points are illustrated by Figure 9. The green line is the orbit with a period of 3/43 days that is as close as possible to a circular orbit. Its distance from the centre of the Earth is 3 km less when the spacecraft is close to one of the poles than when it is over the equator. This 3 km difference corresponds to the short-periodic perturbations due to the Earth's oblateness. As the radius of the Earth at the equator is about 21 km greater than at the poles, the spacecraft's altitude over the equator will therefore be 21–3 = 18 km lower than that close to the poles. After one month, the cumulative perturbations would have deformed this

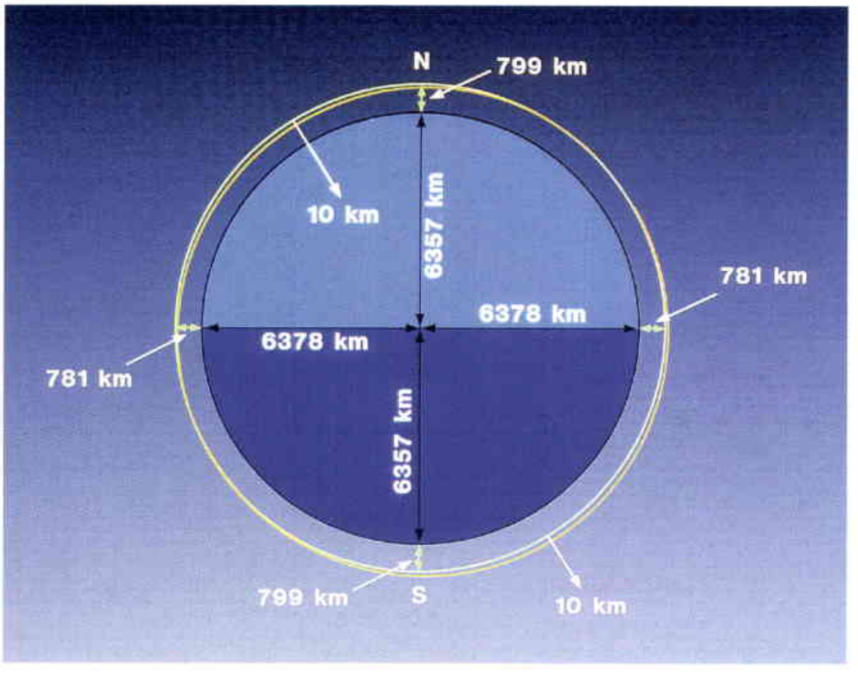


Figure 9. Initial, almost circular orbit and the perturbation in its shape after one month

orbit by about 10 km, as indicated by the yellow line. This deformed orbit would have essentially the same orbital period, but the spacecraft's velocity would be less constant, with it moving faster in the parts with reduced altitude and slower where the altitude has increased.

The amount of deformation will be quite sensitive to the precise shape of the initial orbit. It is possible in practice to select an initial orbit such that this deformation is essentially zero. For ERS-1, this is achieved by having an orbit that is 17 km lower close to the North Pole than close to the South Pole. For a 3 day repeat cycle, this means an altitude of 807 km close to the South Pole and 790 km close to the North Pole. Such an orbit that does not change is often called a 'frozen' orbit.

Even the faint 'triaxiality' – the dependence of the gravitational force not only on latitude and altitude but also on longitude – of the Earth will result in non-negligible perturbations. If an optimally selected 'frozen' orbit is used, however, all of these perturbations associated with the Earth's gravitational field will essentially be periodic, with a period equal to the orbital period or to the rotational period of the Earth, i.e one day. After *n* days and *m* orbital revolutions, these periodic perturbations repeat and there are no significant implications for the accuracy with which a repeat pattern can be implemented. The westward shift of the successive crossings of the Earth's equator from south to north will not be exactly $n/m \times 360°$ and the successive orbits relative to the rotating Earth will not correspond exactly to a longitude shift, but after *m* nodal orbits the path relative to the Earth is repeated just the same.

Having seen that neither the precession of the orbital plane around the Earth's spin axis, nor the periodic perturbations caused by the Earth's gravitational field, limits the accuracy with which a repeat pattern can be implemented, the question remains as to whether there are other secular or long periodic orbital perturbations.

Secular variations caused by air drag and the Sun/Moon

Air drag will reduce the spacecraft's orbital velocity, its altitude, and the nodal period. This drag is strongly dependent on the amount of solar activity taking place. When such activity is high, emissions in the extreme-ultraviolet band (EUV), i.e. at wavelengths of 100–1000 Angstrom, will stir up the atmosphere and increase the molecular density at 800 km altitude. Mathematical models and algorithms are available to compute the air drag on the satellite with an accuracy of some 5% for a given emission in the 10.7 cm band. This emission is constantly monitored by the US National Oceanic and Atmospheric Administration (NOAA) and the results are transmitted to ESOC on a daily basis. Making solar-activity and air-drag predictions for the future, however, is a difficult task.

In order to compensate for the air drag, regular orbit-maintenance manoeuvres are necessary.

The orbit's mean inclination will decrease slowly due mainly to the gravitational forces of the Sun and Moon. This effect amounts typically to 0.02° per year for ERS-1, but this average rate also depends on other factors such as the ground track relative to the Earth's triaxial gravitational field when the spacecraft is in a 3 day repeat orbit. Inclination-correction manoeuvres are needed to compensate for these reductions.

The reference orbits

If there were no air drag, it would have been possible for ERS-1 to have almost repetitive orbits corresponding both to the 3 day and the 35 day repeat cycles. Such theoretical orbits can be derived in the form of the motion of a drag-free spacecraft with respect to a geodetic coordinate system that rotates with the Earth. This fixed geodetic coordinate system is implicitly defined by the longitudes, latitudes and altitudes that are assigned to certain geographical points, and by the size of the reference ellipsoid used to approximate the shape of the Earth. These theoretical orbits are referred to as the 'reference orbits'.

If the spacecraft is initially put into a position and given a velocity that corresponds to this reference orbit, after a few days air drag will result in the situation shown in Figure 10. The spacecraft will essentially follow the path of the reference orbit, the difference being a slight altitude loss of the order of say 20 m. The important difference will be an along-track deviation of several kilometres, the real satellite being ahead of the 'reference orbit' position. It will therefore arrive at a certain latitude 'too early', and the ground track will be east of the nominal ground track corresponding to the reference orbit.

At the equator, the velocity of the Earth's surface caused by the planet's rotation is about 0.5 km/s and its direction of motion is almost orthogonal to the spacecraft's flight path. In order to have a ground track deviating less than 1 km from that of the reference orbit at the equator, the along-track deviation must not correspond to more than 2 sec travelling time. At the extreme northern and southern points, the spacecraft travels in a westerly direction. An along-track deviation between the actual spacecraft orbit and the reference orbit of a few kilometres will therefore not have any effect on the ground track. For intermediate latitudes, the sensitivity of the ground track to along-track deviations will be between these extreme cases.

Orbit-maintenance manoeuvres

The orbit control cycles to compensate for the air drag are applied as follows. At the beginning of a control cycle, the spacecraft should be in an orbit that is very close to the reference orbit, but with a slightly higher altitude, by of the order of 20–50 m. The phase of the spacecraft should be such that it is ahead of the reference orbit by about 2 sec. This will then result in an initial ground track that is to the east of the nominal ground track, the maximum deviation of 1 km being at the equator crossings. But as the orbital period in a higher orbit is somewhat longer, the along-track deviation between the spacecraft's actual position and the nominal reference position will decrease until the spacecraft will be trailing the reference position, and the actual ground track will be west of the reference ground track. The air drag will in the meantime have reduced the altitude of the actual orbit, resulting in a shorter orbital period. After a certain time,

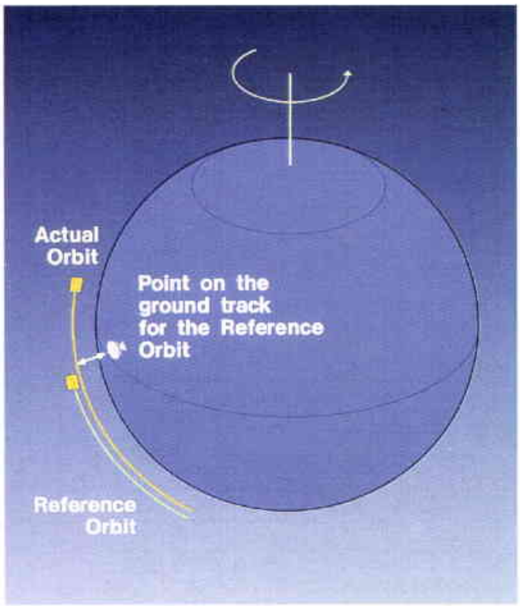


Figure 10. Spacecraft initial position and velocity correspond to the 'reference orbit', but air drag perturbs this orbit and the spacecraft eventually arrives 'too early'

the spacecraft will therefore again be ahead of the reference position and the ground track will be east of the reference ground track.

When the actual ground track is 1 km to the east of the reference ground track, it is then again time to make an orbit-maintenance manoeuvre. This is generally made as a two-burn manoeuvre, with half an orbit between the burns (Fig. 11). The sizes of the burns and the positions in the orbit at which they are made are selected such that the shape of the the orbit after the manoeuvre is as close as possible to the periodic reference orbit, the only difference being an altitude bias of the order of 20–50 m, uniformly distributed around the orbit. The size of this bias is computed each time based on the predicted solar activity. The target is to have a maximum bias and therefore a maximum control cycle, with the constraint that when the air drag has removed this bias and the period is synchronous with the Earth's rotation, the ground track at the equator is at most 1 km to the west of the reference ground track.

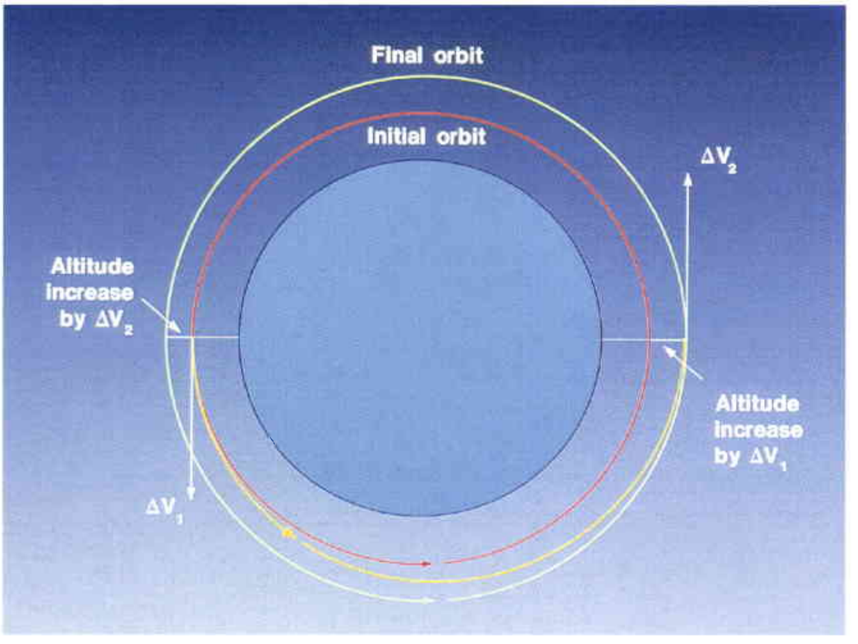


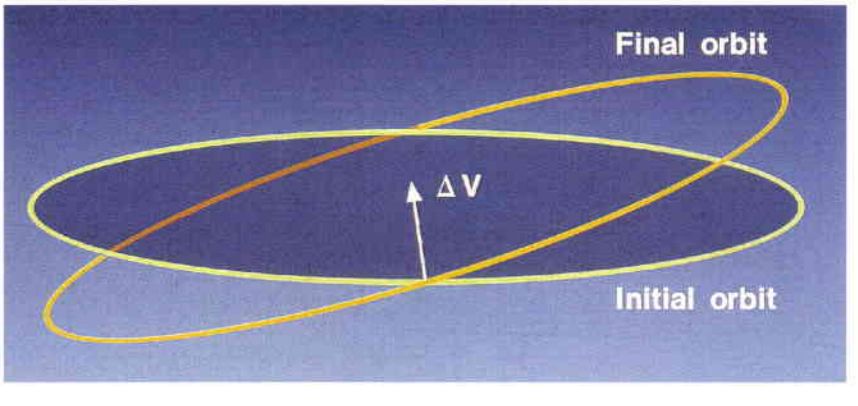
Figure 11. Two impulse manoeuvres raise the orbit after altitude loss due to air drag

The frequency with which these orbit maintenance manoeuvres must be applied to maintain a ground track to within ±1 km of the reference ground track depends on the prevailing degree of solar activity. For 1991 and the first quarter of 1992, solar activity was high and control cycles were typically in the order of 1 to 3 weeks. Later in 1992, solar activity has been lower and control cycles of 1 month or more are possible.

Inclination correction manoeuvres

As the radius of the Earth close to the pole is 6357 km, it is clear that if the deviation in inclination between the reference orbit and the actual orbit is larger than 1/6357 rad or 0.009°, the deviation between the actual ground track and the reference ground track will exceed 1 km close to the poles. As the inclination decreases due to natural perturbations at an average rate of about 0.02° per year, it can be concluded that at least once per year an inclination correction manoeuvre is necessary to maintain the ground track in the deadband of ±1 km relative to the reference ground track. At intermediate latitudes, for example in the 50° to 70° band, both the control cycle to compensate for the air drag described above and the deviation in inclination play a role, and the inclination must in fact be kept within a narrower deadband than ±0.009° in order to maintain the ground track within the limits of ±1 km everywhere.

Figure 12. Changing of the orbital plane by an 'out-of-plane' manoeuvre



Also, the precession rate of the orbital plane is affected by the inclination. However, if the inclination is allowed to drift from the maximum to the minimum of a control deadband for which the centre corresponds to a strictly Sun-synchronous value, the average precession rate will be the correct one. If this control deadband is as narrow as ±0.009°, the deviations from the average rate – a higher precession rate at the beginning and a lower one at the end – will cause no problems.

An inclination correction manoeuvre can be made either at the ascending or at the descending passage through the equatorial plane, as shown in Figure 12.

Conclusions

The ground track of ERS-1 has been kept within a control deadband of ±1 km since the spacecraft's launch. To achieve this, orbit maintenance manoeuvres to compensate for the air drag were needed every 1 to 3 weeks in 1991, and during the first quarter of 1992 when solar activity was high. Later in 1992, solar activity has been lower and intervals of 1 month or more between manoeuvres have been possible.

As the air drag cannot be predicted accurately in advance, daily monitoring of the orbit-determination results and of the solar-activity reports is essential. Based on this information, it will sometimes be necessary to implement orbit manoeuvres at rather short notice. With the present low solar activity, however, the situation is rather relaxed in this respect.

Inclination correction manoeuvres need to be made roughly every 9 to 10 months. The drift in the inclination of ERS-1's orbit can be accurately predicted for long periods ahead and those inclination correction manoeuvres that are needed can be planned well in advance.

The Training of the New Astronaut Candidates at EAC

K. Damian
Astronauts Support and Training Division, European Astronauts Centre (EAC), Cologne, Germany

Introduction

The European Astronauts Centre (EAC), ESA's youngest establishment and the home base for all ESA astronauts, is responsible for all European astronaut matters, and in particular for the selection, medical surveillance and support of astronauts and for their training. EAC has been created in order to develop a centre of expertise for the Agency's manned space activities for the 21st Century.

The first training activities to be undertaken at the European Astronauts Centre have recently been completed, with five new European astronaut candidates receiving an intensive introduction to ESA, the European space programmes, and basic space science and technology. The instructors for these first courses, given in June and July, were a mixture of key ESA personnel and recognised experts from universities and scientific institutes prominent in the space field, as well as experienced astronauts.

Since the Astronauts Centre's foundation in 1990, activities at EAC have focussed initially on the selection of new astronaut candidates and on the development of a training programme to support ESA's manned space activities. The first astronaut selection cycle was completed in May of this year with the choice of six candidate astronauts. Other noteworthy EAC activities in 1992 have been the supporting of the missions by the ESA astronauts Ulf Merbold (IML-1) and Claude Nicollier (Eureca), and by the Belgian astronaut Dirk Frimout (Atlas-1).

We report here on both the Introductory Training that has recently been conducted and on the Basic Training programme that is in preparation for 1993, which together represent the first steps within the overall European astronaut training programme. The complementary training of the European astronaut candidates by NASA and the plans to cooperate with the CIS's Star City activities are also addressed.

First training successfully completed

Four astronaut candidates took up duty and began training at EAC on 1 June this year. Another candidate joined the course later in June, and the sixth is still completing his test-pilot training at the Empire Test Pilot School in the United Kingdom (Fig. 1). Two of the candidates were subsequently enrolled for NASA Mission Specialist training, which started at the beginning of August.

The primary objective of the initial 'Introductory Training' was therefore to provide those candidates who were assigned for NASA training with a solid introduction to ESA, its programmes and other European and cooperative space programmes in order to help them to identify themselves with ESA and to act as its representatives (Table 1). It also provides the candidates with an introduction to, and helps them to integrate into, EAC as the base that will provide them with the requisite support throughout their professional careers as astronauts.

The classroom training includes basic instruction in space technology and operations, an overview of the Agency's major programmes, the history of unmanned and manned space activities, space law and organisational aspects of the Agency. The practical training includes primarily physical training (Fig. 2) at a fitness centre under the guidance and supervision of experienced instructors, who also lecture on the human-physiology aspects of training and the basics of sports medicine.

To prepare the astronaut candidates for their role as prominent ESA representatives in the public eye, a course in media skills is provided by a specialist company. This course is supplemented with a briefing on the Agency's public-relations policy.

Visits to the Spacelab Simulator and the

Figure 1. The European Astronaut Candidates at EAC. From left to right: Christer Fuglesang (Sweden) Pedro Duque (Spain) Marianne Merchez (Belgium) Maurizio Cheli (Italy) Jean-François Clervoy (France).

Thomas Reiter (Germany) will join EAC in December

Table 1. Introductory Training

Content	Hours
Introduction to EAC	10
ESA administration, staff rules, legal aspects	6
Goals of space activities, science and application activities	5
History of space activities, current space programmes worldwide	11
European space programmes	18
ESA's role, European space industry	6
Visits to ESTEC, ESOC and ESRIN	15
Orbital environment	2
Life sciences	5
Materials science	7
Remote-sensing principles and technology	10
Physical training, sports medicine	14
Computer skills, office automation	10
Public-relations briefing, media skills	10
Spacelab systems and operations	4
US professional and social environment	11
Total	144

Microgravity User Support Centre in Cologne complement the theoretical tuition, while visits to the other ESA Establishments give a first impression of the wide variety and scope of ESA's scientific, technological and operational activities.

The team of instructors is made up of staff from the respective programme directorates and administrative services of the Agency, experts from universities and scientific institutes, experienced ESA and national astronauts, contractors and EAC staff. They are able to provide not only first-hand knowledge and expertise in the specific spheres of interest, but also the opportunity for the astronaut candidates to meet and get acquainted with key persons from both ESA and other space organisations. The lectures by experienced astronauts have been particularly appreciated by the candidates, and the ensuing discussions often extend far beyond the formal training time.

A total of 144 h of formal training have been provided by 39 instructors (6 EAC, 19 other ESA and 14 external instructors). Work books have been produced for each lecture on the basis of inputs by the instructors, with the condensed content of each lecture, the presentation handouts, references, a glossary, and recommendations for further reading. The EAC documentation system and the EAC library provide access to additional literature.

As this Introductory Training was the first training conducted by EAC, particular emphasis has been given to strong feed-back via questionnaires for instructors and trainees, through the weekly training meeting and informal discussions, and via the final reports. This feedback will provide important input for the further development of the Centre's training activities.

The European training concept

The Introductory Training was the first step in the implementation of the European astronaut training programme that has been under development by EAC since 1990 in support of the Agency's manned space activities, primarily the Columbus and Hermes Programmes, but also the Columbus Precursor Flights (Spacelab; Eureca launch and retrieval).

The programme baselines of Columbus and Hermes contained several types of missions, including combined missions involving both programmes. The interface to NASA and to other partners had to be taken into account for the Columbus Attached Laboratory mission and the Precursor Flights. A modular training programme was therefore chosen as the appropriate response to these requirements. This modular concept will also make it easier to meet new requirements resulting from the continuing evolution in the Agency's manned programmes.

The training-concept development effort did not start from zero two years ago in that a number of studies had already been conducted in the context of the Columbus and Hermes Programmes and by national agencies. As the definition of the on-board tasks to be conducted by future European astronauts was still in its infancy at the time of these earlier studies, they had to be founded largely on assumptions based on the cooperative missions already undertaken with the United States. In particular, the training experience gained through the Spacelab missions constituted an important input.

All of these inputs had therefore to be consolidated into a formal training programme, subject to review by an international group of experts, including experienced astronauts from Europe, the USA and the CIS. It represents the present astronaut training baseline for the Agency, and it will be continuously updated in the context of changing mission scenarios, more mature definition of on-board tasks, and on the basis of the feedback from its implementation and the evaluation of mission performance.

The overall training programme is composed of three phases (Fig. 3):

- *Basic Training* is the first training phase after recruitment and is designed to give candidates the fundamental notions and skills required for their careers as professional astronauts. It starts with a general introduction to the European Space Agency, its programmes and other European and worldwide space activities. It brings the candidates to an appropriate level of knowledge in basic scientific disciplines and in space technology and operations. In addition, it develops the practical skills needed for flying (pilot qualifications), maintaining one's physical fitness, and making public appearances. Basic Training is effectively regarded as a probationary period, satisfactory conclusion of which after one year leads to certification as a European Astronaut.

- *Specialised Training* is the next step, which provides deeper knowledge of specific space systems, such as the Columbus Attached Laboratory, its subsystems and payloads. It is not geared, however, to a specific mission or its operational procedures, but is more directed towards providing an in-depth knowledge of basic space systems and payload operations. Practical skills in such areas as laboratory work will be further developed in this phase, as well as

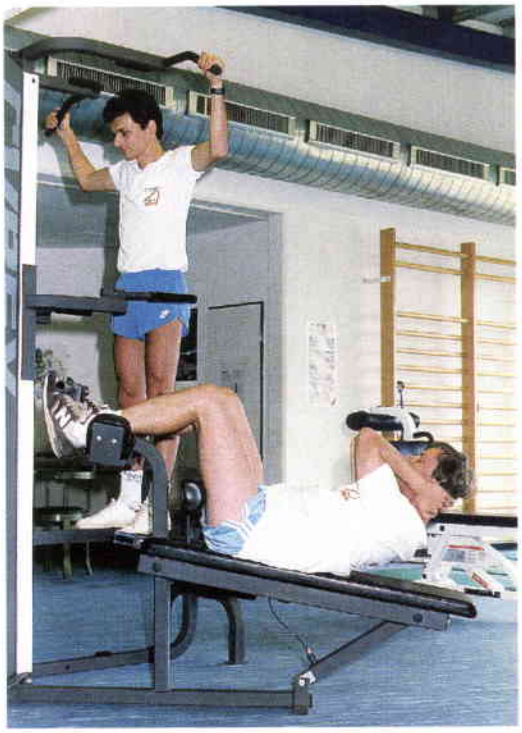


Figure 2. Physical-fitness training

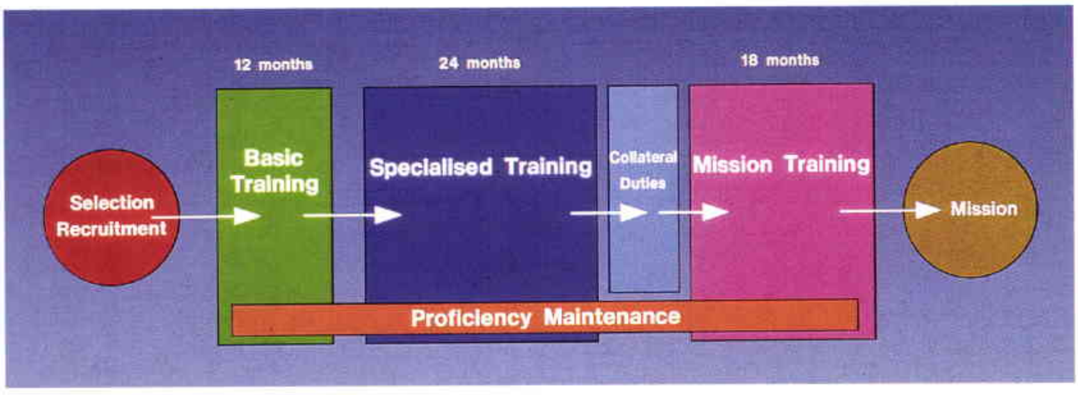


Figure 3. Training programme sequencing

greater proficiency in such disciplines as flying and diving. Specialised Training can be conducted either for a class, or for small groups, as necessary.

The Specialised Training for Space Station 'Freedom' activities will be carried out for an international class which includes US, Canadian, Japanese and European astronauts. This class will be trained at the training facilities of all of the partners, i.e. in Europe for Attached Laboratory systems and European payloads, etc. After two years of successful Specialised Training, astronauts will be eligible for selection for a specific mission, to Space Station 'Freedom' for example.

– *Mission Training* will commence following the selection of the crew for a specific mission. The period between the completion of Specialised Training and mission assignment will be used for associated duties, such as participation in payload development, procedures validation, and ground operations.

The Mission Training will be undertaken by the crew as a whole. Flight-procedures training will be conducted on simulators that will be highly representative of the flight hardware. Emphasis will be placed on appropriate coordination and interaction between the onboard and ground crews. Important mission sequences will be rehearsed by the crew via 'integrated simulations' using a representative simulator of the full space element linked to the appropriate Control Centres.

The Mission Training phase will last 18 months. For the Space Station 'Freedom' Programme it will be partly conducted in Europe also, primarily in the context of European payload training.

The first Basic Training course

The first full Basic Training course at EAC will be conducted in 1993. It will consist of the four blocks of activities shown in Table 2, involving a total of around 1000 h of formal training. The 'Introduction' block will complement and reinforce the Introductory Training that the astronaut candidates have already received.

The 'Integration & Refresher' training block covers fundamentals in science and engineering from mathematics and chemistry, through biology and medicine, to astrophysics, electrical and aerospace engineering. The primary objective here will be to bring all of the candidates to a similar level of knowledge, as a prerequisite for the other courses that will follow. This block of about 140 h will therefore be tailored to the specific educational backgrounds of the trainees.

The 'Instruction' training block goes straight into space technology and covers space systems and operations (200 h) and science disciplines (200 h) like life sciences, materials science, fluid science, space science and Earth observation.

The 'Astronauts Capabilities Training' block (320 h) covers a variety of theoretical and practical abilities likely to be needed by the professional astronauts during their careers, including medical and survival training. The medical/psychological training will include the basics of human physiology and medicine, space physiology, group coordination and stress management. Formal physical training will need to be complemented by sports activities outside duty hours. Parabolic flights will provide familiarisation with a microgravity environment, and survival and rescue training will equip candidates to cope with demanding in-orbit situations and to develop team spirit.

Table 2. Basic Training overview

Block	Tasks
Introduction	Introduction to Space Activities
Integration & Refresher	Fundamentals of Sciences and Engineering
Instruction	Space Systems Space Operations and Procedures Life Sciences Material and Fluid Sciences Earth Observation and Space Science
Astronauts Capabilities Training	Medical and Psychological Training Physical Training Flight Training Scuba Diving Space Adaptation Training Behaviour under Extraordinary Conditions Laboratory Skills Training Computer Training Language Workshop Media Skills Training

Figure 4. New EAC accommodation: the Crew Training Complex

The hours currrently allocated to the various training units are target figures which still need some fine tuning in the course of curriculum development. The total of 1000 h of formal training will be divided over 40 weeks, with 5 h of training per day. This is intended to allow some hours per day for private study and for the support of other activities making use of the candidates' specialist expertise.

The detailed curriculum for Basic Training in 1993 is being developed by the EAC Support and Training Division, supported by technical-assistance contracts, and in close collaboration with ESA, industry and scientific experts, and with strong involvement on the part of experienced astronauts.

International cooperation

The training activities at the European Astronauts Centre are aimed at building up European expertise, but they will also form part of an international cooperative endeavour. In the framework of the International Space Station 'Freedom' Programme, a common training concept to which all of the partners are expected to contribute is under development. Each partner will conduct their own Basic Training for their own astronaut candidates, but there will be an agreed 'common core' to this training.

As noted above, two European candidate astronauts have already started Shuttle-oriented Mission-Specialist training at NASA's Johnson Space Center in Houston (USA). The experience gained by these two candidate astronauts, and by an EAC training engineer who is currently also stationed at JSC, will provide a further contribution to the ongoing development of the European training concept.

Close relations have also been established between EAC and Star City. CIS experts participated in the review of the EAC training concept and negotiations on closer cooperation are under way. The planned cooperation will include a four-week training period for three European astronaut candidates at Star City in the last quarter of 1992, participation by Russian instructors in EAC Basic Training in 1993, and the conducting of important parts of this training at Star City in the second half of 1993. This will be an invaluable experience for the candidates and the accompanying training engineer, which will hopefully lead to the eventual participation of European astronauts in Mir missions.

Conclusion

Two years after the creation of the European Astronauts Centre in Cologne, the first six astronaut candidates have been selected and the first training activities have already been completed. Preparation for the Basic Training programme to be conducted in 1993 is the current challenge facing the EAC training team, pending the outcome of the ESA Council Meeting at Ministerial Level in Granada (E) on 9/10 November 1992.

'Commonality' – A Keyword for the Ground-Segment Infrastructure

M. Guerin
Simulation and Electrical Facilities Division, ESTEC, Noordwijk, The Netherlands

H. A. Laue
Management Support Office, ESOC, Darmstadt, Germany

One of the main problems faced by space projects today is the discontinuity that occurs between the development and operations phases, which are managed by different teams under different contractual arrangements. The problems that most frequently arise are: difficulty in taking operations requirements into account in the spacecraft design, inadequacy of products delivered by the development contractor to the operations teams (e.g. documentation), insufficient end-to-end validation of the complete system (both space and ground segments) before launch, and lack of commonality between elements of the Ground-Segment Infrastructure (GSI). This article does not propose a miracle solution to the overall problem but, more modestly, addresses the concept of GSI commonality, and its application to the Mission Control System (MCS) used for spacecraft operations and to the Electrical Ground-Support Equipment (EGSE) used for electrical testing.

Introduction

The Agency's Ground-Segment Infrastructure (GSI) includes five prime elements:

- Electrical Ground-Support Equipment (EGSE), used for the electrical testing of spacecraft during the Assembly, Integration and Test (AIT) phase of the development programme.
- Mission Control Systems (MCS), used to operate spacecraft during their in-orbit lifetimes.
- Station Control Systems, used to operate ground stations either locally or remotely.
- Spacecraft Simulators, used to simulate (parts of) the spacecraft's behaviour, to validate the MCS and its operational configuration, and to train operators.
- Ground-Support Equipment for payloads.

Of the five, the EGSE and the MCS have significant potential for commonality, since they have equivalent functions with respect to the spacecraft, as indicated in Figure 1.

Commonality

It is important to note here that commonality is, of course, not an end in itself, but has to be justified in terms of benefits to the Agency as a whole and to its programmes. The objective is not necessarily to re-utilise the same set of equipment for operations after it has been used for testing, but rather to ensure the maximum level of common design effort and common elements between the hardware, software and procedures of the two systems, and to make sure that maximum benefit is derived from previous similar developments and applications.

This should allow direct savings in development costs by:

- lowering unit costs due to larger production runs, and spreading development costs over more units
- eliminating multiple development efforts for elements with essentially the same functionality
- reducing both financial and schedule development risks, and generally providing better control over industrial costs
- providing a better-quality product.

In addition, there are also indirect cost benefits to be obtained through reduced validation and training efforts as a result of common internal and external (man/machine) interfaces.

With these objectives in mind, the concept of commonality can be applied in two ways (Fig. 2):

(a) Commonality within a given project, with commonality being ensured between the project-specific EGSE and the MCS for that particular project. This is known as 'vertical commonality'.

(b) Commonality between the EGSEs of several different projects, the objective being to ensure the maximum of commonality between the project EGSEs on the one hand, and between their MCSs on the other. This is referred to as 'horizontal commonality'.

Present situation
The potential advantages of commonality of ground systems are generally recognised and some success has been achieved in specific areas. Depending on the particular interests of the party concerned, emphasis in these actions has varied between the horizontal- and vertical-commonality approaches. However, these limited efforts have not yet allowed the Agency to capitalise on the full spectrum of potential advantages offered by a coherent commonality policy, and this in turn has led to a certain relaxation in the drive towards commonality.

Horizontal commonality
EGSE
Electrical Ground-Support Equipment (EGSE) is the collective name given to the tools required for the electrical testing of flight systems. Due to the nature of the tests to be performed, it is necessary to automate the test process to the maximum degree possible, which results in a heavy reliance on computerised systems.

At system level, the EGSE usually contains a master computer for overall system-management purposes, with separate computer-controlled test equipment dedicated to specific satellite subsystems and payloads, integrated by means of a local-area network.

The facilities available to the test personnel via the EGSE can be summarised as:
(a)Test preparation
- definition of a satellite telemetry and telecommand database
- definition of automatic test procedures in the appropriate test language
- definition of satellite status displays.

(b) Test execution
- execution of automatic test procedures
- continuous monitoring of satellite telemetry (and telecommands)
- generation of real-time status displays
- satellite stimulation
- raw- and processed-data archiving.

(c) Test evaluation
- replay of archived data
- test-report generation
- data processing.

Until 1979, it was ESA policy to treat EGSE as 'Agency-furnished equipment'. This had the advantage of ensuring horizontal commonality between projects (e.g. the acceptance of the ETOL system as a de-facto standard on most Agency projects),

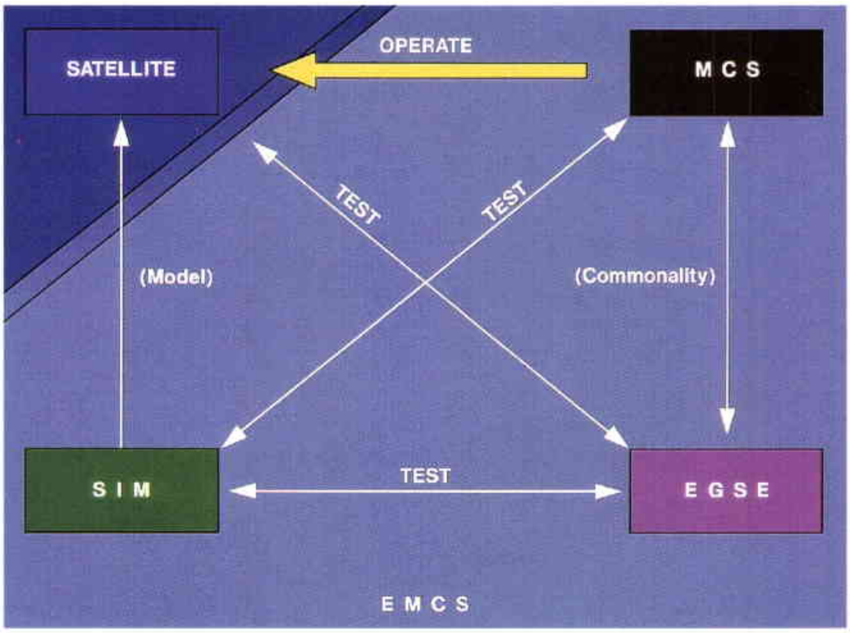


Figure 1. Checkout and control ground systems

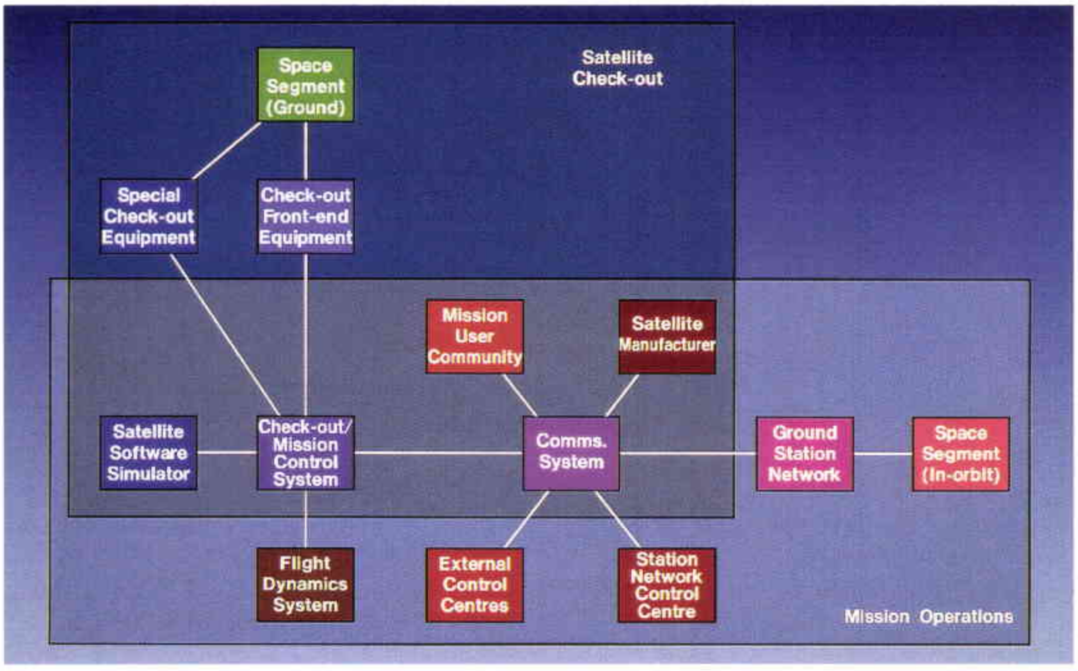


Figure 2. The horizontal- and vertical-commonality concepts

but created organisational and contractual problems between the ESA project group and the prime contractors. The Agency then decided to modify its approach and to encourage prime contractors to take over responsibility for the provision, maintenance and operation of checkout stations. This new policy was gradually implemented, and now is applicable to all ESA projects.

The result of this policy has been that Agency-produced software has been licensed to a number of prime contractors and EGSE suppliers in order to assist them in setting up their own infrastructure. A number of companies are now proficient in EGSE following the standards developed by ESA.

In the meantime, the standardisation and prototyping activities by ESTEC have, through continued liaison with industry, resulted in the introduction of new technologies in the EGSE for new projects. As a consequence, the level of EGSE standardisation is now in the realms of architecture and functional requirements, rather than at the level of physical implementations. However, this has been achieved by applying 'technical common sense', rather than via a policy as such. An unavoidable consequence of this evolution is the observed tendency to depart from horizontal commonality, each project developing its own EGSE as a function of its requirements and of its industrial structure.

MCS

The Mission Control System (MCS) supports a mission during its operational phase. It ensures the remote interface between the human operator on the one hand and spacecraft and payload on the other, in such a way that the mission objectives are fulfilled and that mission products and services are maximised. The MCS encompasses all of the functions necessary to validate operational procedures, to plan the mission activities, to perform the monitoring and control functions, and finally to evaluate the mission progress against the plan.

A key aspect of the MCS is its robustness against human errors, which could adversely affect the mission. The degree of checking of human inputs with respect to proper authorisation and in terms of functional correctness is therefore of prime importance. Although the man/machine interfaces should have enough flexibility to allow the mission information to be accessed in the most convenient manner, this flexibility must not lead to ambiguous or hazardous situations whilst conducting spacecraft operations, particularly in a multi-satellite/multi-operation environment.

Another distinct feature of an MCS is that the nominal operational activities are planned in advance and that any deviation from the original plan needs a rapid evaluation of the situation, followed by re-planning. A system outage during critical operations cannot be tolerated.

The basic functions of the MCS are comparable to those of the EGSE, but the MCS contains additional functions such as flight dynamics, mission planning etc., which directly support the control and monitoring functions. Listed by phase, these functions are as follows:

(a) Mission preparation
- definition of satellite-characteristics (telemetry, telecommand) databases
- preparation and validation of nominal and contingency operational procedures
- definition of monitoring and control displays and of derived parameters
- establishment of long-term mission planning
- preparation of the Flight Operations Plan.

(b) Mission implementation
- spacecraft and payload monitoring
- implementation of operational procedures as per the Flight-Operations Plan
- analysis of anomalies and contingency recovery
- determination and control of satellite attitude and orbit
- trend analysis
- short-term mission planning and contingency re-planning
- payload reconfiguration in response to mission objectives
- receipt, pre-processing, checking, annotation, distribution and archiving of mission products.

(c) Mission evaluation
- mission-report generation
- technological evaluation of payload and subsystem performance.

In 1974, ESOC decided to implement a Multi-Satellite Support System (MSSS) with the objective of supporting several missions concurrently from the same system. The MSSS is a clear and successful demonstration of horizontal commonality in an MCS that has been used for a number of ESOC-controlled missions, including all telecommunications satellites, the Exosat and Giotto scientific satellites and all Meteosats in their low-Earth-orbit phases (LEOPs).

Copies of the MSSS system are implemented at other sites, such as the Redu Control Centre in Belgium for the ECS satellites and at Fucino in Italy for Olympus, and recently also by Inmarsat for their second-generation communications satellites.

Starting in 1984, ESOC has evolved this concept into the 'Dedicated Mission Support System' (DMSS), whereby dedicated hardware configurations will support different missions, but all based on a common and reusable software infrastructure package, known as the Spacecraft Control & Operation System (SCOS). The SCOS was used for Hipparcos and will also be used for ERS-1, Eureca and ISO, and in future releases for all missions supported by ESOC.

Vertical commonality

The situation in terms of vertical commonality differs from project to project, as the following examples demonstrate.

(a) Giotto

Giotto was the first project in the ESA Scientific Programme to partially implement 'vertical commonality'. It was primarily exploited in the experiment area, where equipment built initially for the development of the experiments was subsequently used as a node of the system-level EGSE for experiment testing at integrated system level, and then again as a node in the Operations Centre, serving as a 'quick-look device' during the actual mission. This use during operations required most of the EGSE, a situation that has been rectified through higher levels of standardisation (see ISO below). Although this approach was successful, it should not be forgotten that it addressed scientific data processing (quick-look) and not the spacecraft operations proper.

(b) ISO

The principles established with Giotto have been adopted in the ISO scientific project also, and refined to improve the degree of commonality. The scientific workstations defined for the ISO operations will be used first in the EGSE at system level for integrated testing (reverse of the Giotto case). This is intended to be achieved through a higher level of standardisation of the interfaces between these workstations and the supporting services (EGSE and MCS). In addition, the databases used in the EGSE and in the MCS, which are very similar in both content and use, will be derived from the same satellite database prepared by the prime contractor.

(c) Columbus

A major new development has commenced on a concept for a Columbus Ground-Support Infrastructure, which consists of the Software Development Environment (SDE), the EGSE, the simulation facilities (CSF), and the Mission Preparation Software (MPS). In this context, a number of project-wide standards will be prepared to ensure commonality across the areas listed above. These standards include industrial standards such as the ADA programming language, X-Windows, VME bus, and IEEE-488, together with such Columbus standards as the Human Computer Interface, User Control Language (UCL) and software-engineering standards.

(d) Ariane

The situation in the Ariane Programme is somewhat different as far as commonality is concerned, due to the particular nature of the devolved responsibilities. Vertical commonality has, however, been studied for Ariane-5 and it is hoped that its implementation will result in common facilities from bench test to launch.

Limits to commonality

Differences in functional requirements

Despite the obvious similarities in many areas, there are some fundamental differences between the domains of EGSE and MCS. The EGSE, as explained earlier, is constructed in a way that mimics the satellite construction sequence. Strong emphasis is placed first on ensuring that specific subsystems are correctly constructed, and then on ensuring that they operate correctly when integrated into a system.

Another point is that testing is driven by the need to operate all satellite subsystems in all possible modes, including all redundancies. It is generally not required to operate test procedures that mimic the in-orbit procedures (and often not possible due to environmental or time constraints). Since the satellite is readily accessible, there is no requirement to consider mission safety. The satellite can be exercised in ways that would only be used operationally as a means of overcoming a failure. Redundancy in the EGSE is generally unnecessary, the only justification being on project-schedule grounds.

An MCS system, on the other hand, must guarantee an almost 100% operational availability, especially during critical mission phases. A longer outage may have drastic implications for the mission. Even under these conditions, however, hardware and software maintenance must be possible. This requires a rigorous configuration control mechanism during the operational phase of the system, which may last for several years.

The system is usually used concurrently by a number of people performing different functions. It must therefore be heavily protected against unauthorised or unplanned use. The utilisational flexibility must be limited to just the necessary functions, so that the user is not faced with unusual or ambiguous situations.

All of the activities surrounding the MCS for the mission must be precisely planned, with alternative scenarios in the event of contingencies. In some cases, new operational procedures must be simulated against a spacecraft model before being used in real operations.

The MCS system performs the mission-specific flight-dynamics activities that contribute to the mission control and evaluation activities. This subset of functions must have a clear interface to the rest of the system.

Procurement aspects

The current methods for procuring EGSE and MCS facilities are radically different. The EGSE is procured by each project via the prime contractor for the satellite. Commonality is generally derived from the previous experience of the prime contractor and/or his subcontractors.

Up to now, the development or specific tailoring of MCS systems has been pursued under centralised control by ESOC. Although various industries have participated in the actual implementation of such systems, ESOC has ensured their convergence around a well-defined technical concept and development policy.

Project time scale

Another obstacle to vertical commonality lies in the project time scale. The EGSE is conceived during the project's design phase (Phase-B), whilst project-specific requirements on the MCS appear only during the main development phase (Phase-C/D), when the spacecraft detailed design can reveal operational constraints that cannot be satisfied by the existing common infrastructure. It is therefore usually difficult to incorporate project-specific MCS requirements into the EGSE specifications, and consequently it is highly probable that EGSE developments will be of limited use when MCS development starts.

Prospects for improvement

Agency policy

The accepted advantages of commonality, including an improved transition from development to operations and reduced technical risk, constitute a strong argument for the Agency defining and adopting a coherent policy in this domain. This topic is already the subject of discussions between ESTEC and ESOC and one objective of this article is to stimulate wider discussion within the European space community also, with the goal of formulating an Agency-wide policy aimed at harmonising procedures and methods for the operational approach throughout the entire life-cycle of the spacecraft.

Standardisation

Recognising the need for better coordination of EGSE and MCS development, ESTEC and ESOC have established a joint committee under the authority of the Telematics Supervisory Board – the Committee for Operations and EGSE Standards (COES) – with the aim of identifying the scope for increased commonality and the setting of common standards in this area for future ESA programmes (Fig. 3).

A data-processing system architecture and its functions are dependant on the data structures it manipulates. For this reason the COES, with its limited resources, has first addressed the management concept for CCSDS Telemetry and Telecommand Packets. This will be the subject of the first COES standard (ref. ESA PSS-07-101, Packet Utilisation Standard), which is now in the final stages of approval prior to publication. It defines the protocol between a spacecraft onboard application and a ground system.

The EGSE and MCS will have to deal with the same packet and in the same way. The functionalities of these two systems could therefore be made compatible for a large part in such aspects as: the satellite description database, operational/test procedure database, telemetry presentation and monitoring functions, man/machine interface and language.

The COES's second task is the specification of the common and standard requirements/functions of these systems, reducing to a minimum the specific (non-common) requirements for test and validation on the one hand, and operations on the other.

Only with such standards available and in operation can one implement a system that

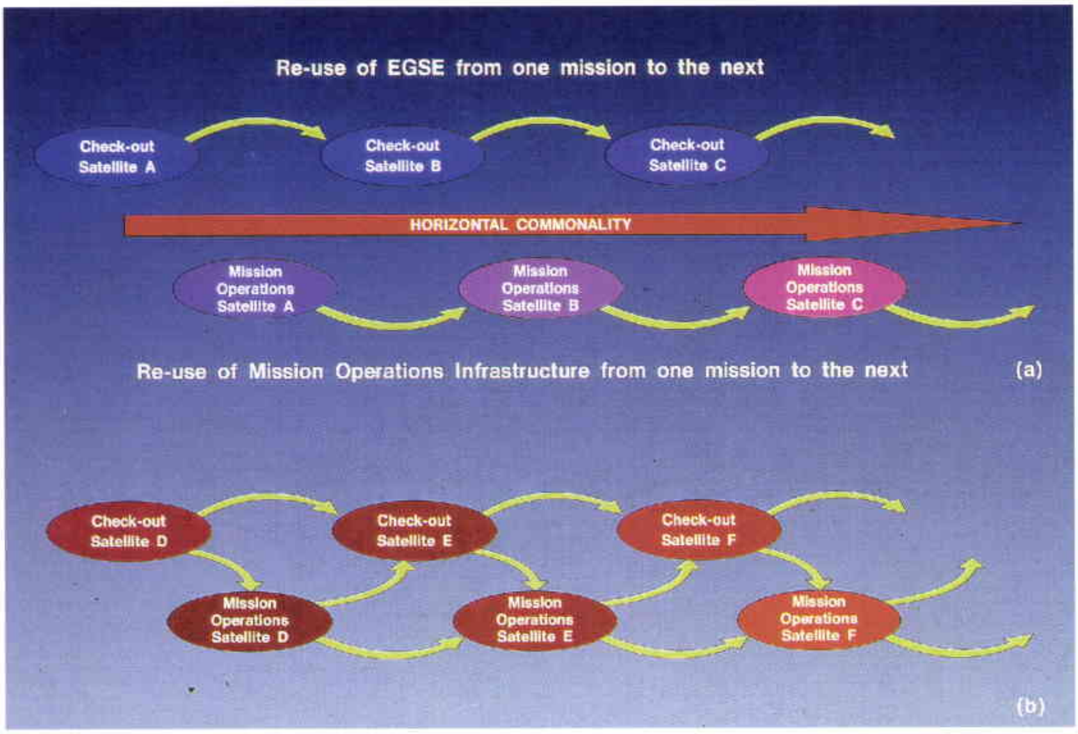


Figure 3. Schematic of EGSE and MCS commonality

should be configurable either for checkout or for operational use, and hence one that can be 'vertically' reused on the same project.

Technology

Elements of the future ground segment are being developed by ESOC and ESTEC in preparation for future missions. The opportunity must be taken in the context of these developments to implement commonality at the prototype level in preparation for the operational systems. Common ESTEC/ESOC proposals that have recently been made in this respect identify three particular courses of action:

Common elements

There are two important domains of commonalities: (i) the Human Computer Interfaces defining how the system is used from the workstations, covering such aspects as satellite data presentation (e.g. graphics, synoptics, etc.), how the workstation is operated, and the command language; (ii) the databases describing the satellite characteristics (e.g. telemetry, telecommand), the computer interface characteristics (display templates, user privileges, etc.), and the spacecraft operations knowledge (procedures, failure cases, etc.).

Pilot implementation

A common implementation can also be envisaged, with a configurable system that could be configured for a particular subset of functions or enlarged with other specific functions.

Potential use of EGSE during MCS development

In the life cycle of a project, the EGSE system is needed much earlier than the MCS system. This can be used to advantage when validating the MCS database, or by using the EGSE to test the spacecraft simulator, which itself is then used to test the MCS system. It would also allow the operations staff to be involved earlier in the mission-preparation phase. This approach is presently being tried experimentally at the technology-prototype level.

Conclusions

Commonality between elements of the Ground Segment Infrastructure (namely Electrical Ground Support Equipment and Mission Control Systems) is a key element in the transition between the spacecraft development and operations phases of a space mission. Experience shows that can be difficult to implement this commonality for a number of reasons, as we have discussed above. Nevertheless, the advantages to be reaped in terms of cost savings and reduced technical risk are such that the efforts necessary to achieve the commonality objectives that have been outlined are duly justified.

Nécessité et gestion d'archives historiques de l'Agence

A. Dattner, G. Lafferranderie & J.M. Palayret
Direction de l'Administration, ESA, Paris

L'Agence est grande productrice de documents; lesquels conserver, pour quelles raisons, comment, pour combien de temps, comment organiser leur accès et par qui? Voilà quelques-unes des questions qui se posent et qui amènent à songer à élaborer une politique des archives historiques* de l'Agence. Un début de réponse a été apporté par la signature d'un 'contrat de dépôt' avec l'Institut universitaire européen de Florence.

Pourquoi cet intérêt pour une politique d'archivage et pour une politique faisant appel à des moyens externes?
Le premier point est fort simple: l'Agence ne disposait pas – et ne dispose pas – d'archives centrales qui permettent de stocker, de classer et de retrouver les documents et qui donc permettraient de détruire – sans avoir à les photocopier au préalable – les documents. L'absence d'archives centrales mais aussi d'un personnel professionnel chargé de les gérer, engendre l'accumulation d'archives personnelles ou par Etablissement. En outre, contrairement à d'autres Organisations européennes, l'Agence dispose d'Etablissements sur les territoires de ses Etats membres: chacun de ces Etablissements produit des documents spécifiques et veut aussi se constituer des collections de documents de portée générale.

Cette absence de politique produisit comme il fallait s'y attendre un engorgement des locaux de dépôts de documents.

A un moment ou à un autre une décision drastique est à prendre. Que jeter? Qui va alors affronter la poussière, essayer de reconstituer les dossiers, comment décider que tel document a plus ou moins d'importance que tel autre?

Il y a par ailleurs des documents que la réglementation vous impose de conserver pour des raisons tenant à leur caractère personel et confidentiel (informations médicales ou sur la carrière de l'agent), ou tenant à leur contenu (information de nature commerciale que l'Agence ne peut divulguer sans enfreindre ses obligations contractuelles) et brevets; mais que faire de certaine documentation technique d'autant que certains documents peuvent retrouver un intérêt plusieurs années après leur émission. Et puis il y a le pur intérêt de la recherche historique, de la politique spatiale européenne, comme élément de la politique européenne.

Ainsi se mettent en place des pratiques – non pas une politique – qui peuvent varier d'un Etablissement à un autre et même qui, au niveau d'un Etablissement ne sont ni connues et donc ni coordonnées.

Ces pratiques reviennent d'une certaine façon à l'institution de ce qu'on appelle les archives vivantes – celles que vous avez dans votre bureau et dans les archives de l'étage – et les archives semi-vivantes, celles qui sont envoyées dans des locaux comme 'Grisel' au Siège et dont vous avez besoin de manière occasionnelle. Mais après que faire?

Pour sortir de cette situation, il eût fallu, dès le départ, réfléchir et mettre en place une politique des archives vivantes ce qui implique des méthodes de classement uniformes à travers les services et même les Etablissements. Florence a permis à l'Agence de mieux saisir les données d'une véritable politique d'archives historiques.

Pourquoi Florence?
Au début de 1983 les Communautés européennes décidaient d'ouvrir leurs archives à la recherche dans le respect d'un délai d'accessibilité de trente ans.

En décembre 1984, un contrat signé entre la Commission de Bruxelles agissant au nom de l'ensemble des organes communautaires et l'Institut universitaire européen (IUE) créait les 'Archives historiques des CE' inaugurées

* Lorsqu'on parle ici de documents de l'Agence, on y comprend les documents produits par la COPERS, le CECLES/ELDO, et le CERS/ESRO.

un an plus tard dans les locaux de la villa 'Il Poggiolo' de l'IUE. Cette décision visait à la fois à promouvoir l'idée européenne en renforçant la 'transparence' des différentes institutions et à fournir une base documentaire solide aux recherches portant sur l'intégration européenne.

L'IUE, institut international d'enseignement et de recherche au niveau de 'post graduates', fondé par les Etats membres en 1976, couvrant par ses quatre départements le champ complet des sciences humaines et ayant pour mission de contribuer par son action et son rayonnement au développement du patrimoine culturel et scientifique de l'Europe, constituait dans cette perspective un 'think tank' incomparable.

Il n'est donc pas étonnant qu'une coopération se soit instituée entre cet Institut et l'Agence pour aider cette dernière à constituer ses archives historiques. Deux remarques: la constitution et la gestion d'archives historiques se situent à l'extrémité d'une chaîne qui commence par la constitution d'archives 'vivantes'; le département d'archives historiques de l'IUE ne constitue aucunement le déversoir de papiers de toute sorte qui sont quotidiennement générés par tout service des organisations dépositaires.

Politique des archives historiques

Jusque là l'ESA n'avait pas de politique concertée d'archives. Certains services gardaient tous les documents qui se retrouvaient alors en double, en triple, beaucoup sans intérêt aucun; d'autres faisaient périodiquement le vide et perdaient parfois des documents d'importance.

Disposer d'une politique d'archives historiques a un double objectif: conserver et mettre à la disposition de la communauté scientifique intéressée par l'histoire de la coopération européenne, conserver dans des conditions adaptées les documents essentiels (mettre les documents à l'abri de l'incendie, de l'humidité, etc.), mais aussi les classer, c'est-à-dire évacuer les doubles, les pièces sans importance, compléter les séries, etc.

L'Institut universitaire de Florence vint par l'offre de ses moyens et services apporter une réponse et un 'contrat de dépôt' fut conclu le 12 mai 1989 entre l'Agence et l'IUE. (A noter que l'OCDE qui n'avait pas non plus de politique d'archives a récemment suivi l'exemple de l'ESA et a conclu un contrat de dépôt avec Florence et établi un système d'archives centralisées).

L'Agence édicta un règlement d'accès aux archives historiques (doc. ESA/C(91)10). Ce règlement est une première étape de la politique d'archives historiques de l'Agence (voir Annexe 1).

On retiendra les définitions d'archives, les archives historiques ne constituant qu'une faible part des archives de l'Agence:
- le statut de ces archives historiques
- leur constitution, partie qui appelle en fait tout un développement en amont sur lequel oeuvre actuellement un groupe de travail mis en place par le Directeur général
- l'accès à ces archives.

Sont déposés dans un premier temps les documents portant sur la période allant jusqu'au 31 mai 1975.

L'écriture de l'histoire de l'Agence par une équipe de chercheurs scientifiques de haut niveau est le premier exemple de l'intérêt de ces archives historiques.

Mais lorsque ce contrat de dépôt fut signé, il n'était pas possible de prévoir la masse des documents qui allait être envoyée des Etablissements à Florence sans instruction spéciale. Un système d'identification simple utilisé fut vite dépassé et le besoin d'un système de sélection et de tri parut évident. Plus de 50% des documents envoyés à Florence n'avait rien d'historique. C'était là la conséquence d'un défaut d'archives semi-vivantes et d'un système de classement, et de l'absence d'archivistes professionnels.

Pour pallier tant bien que mal ces défauts, des points de contact furent nommés dans chaque Etablissement, avec une responsabilité dans l'organisation des locaux d'archives. Des mesures de coordination de l'envoi des documents à Florence furent instituées.

Mais le problème signalé plus haut réapparut vite: l'engorgement des archives historiques en l'absence de système de tri et de sélection avant envoi, l'absence de lignes directrices sur les documents à conserver ou à jeter.

Aussi le Directeur général décida-t-il de la création, sous l'autorité du Conseiller juridique, d'un groupe de travail avec mandat de lui présenter pour la fin de l'année 1992 un projet de lignes directrices et d'organisation d'une politique d'archives de l'Agence. Sur quelles bases?

Le 'cycle de vie' documentaire
Par définition un document est à la fois un support matériel et l'information qu'il renferme. Pour apprécier la préservation ou la destruction du support, il importe d'identifier les différentes valeurs d'information que peuvent receler les documents d'une administration au cours de leur cycle de vie. (On laisse de côté les documents dont la gestion relève de la bibliothéconomie pour se limiter aux documents dont l'Organisation a besoin pour accomplir son mandat).

La valeur primaire
Tous les documents d'une organisation ont au moment de leur création une valeur administrative, juridique ou fiscale puisqu'ils contiennent des informations sur les fonctions et les activités courantes de celle-ci. Dans la majorité des cas cette valeur primaire diminue avec le temps: le passage de l'état d'activité à celui de semi-activité marque la frontière entre deux périodes de vie que les documents administratifs traversent plus ou moins rapidement jusqu'à ce qu'ils deviennent inutiles à l'organisation.

La valeur secondaire (ou historique)
Parmi les documents qui ont une valeur administrative décroissante, certains possèdent une seconde valeur, indépendante de l'objectif stricto sensu qui fut à l'origine de leur création, et qui croît avec le temps: la valeur historique ou de recherche. Au moment où leur valeur administrative sera éteinte, ces documents permettront d'effectuer des études rétrospectives sur les activités et les fonctions de l'organisme, son rôle dans un domaine de l'histoire des sociétés humaines. Ces documents sont alors appelés archives historiques et seront conservés de façon permanente, habituellement en un lieu spécifique.

La prise de conscience des conséquences que peut impliquer, pour une organisation ou une entreprise la rétention incontrôlée de documentation est apparue dans les dernières décennies. Elle est le plus souvent liée au problème du manque d'espace auquel ces organisations se trouvèrent confrontées, consécutif à l'inflation des dossiers créés par le développement de leurs activités.

En dépit de cette évolution des 'ressources documentaires', il est encore trop souvent admis qu'une archive est un luxe dont une organisation peut longtemps se passer. Pourtant les raisons de préserver les documents ne sont pas seulement d'ordre légal ou administratif, liées à la gestion courante de l'organisation, elles peuvent aussi lui procurer une histoire. Une organisation qui n'a pas d'histoire se prive d'une partie de cette 'identité de corps' à laquelle les dirigeants, les employés, les partenaires et les clients peuvent se référer ou s'agréger.

Surtout, il convient de mettre en lumière qu'une archive bien organisée, c'est du temps et de l'argent gagnés: maîtriser l'avalanche de papier, c'est éviter qu'elle ne submerge les services mêmes qui l'ont créée, c'est éliminer les surcoûts liés au stockage d'archives inactives, c'est surtout s'assurer que des dossiers d'intérêt vital ne soient définitivement perdus.

Le rôle des archives 'historiques': accès et conservation permanente
Les archives historiques constituent les 'archives définitives' (non-current records) qui ont été évaluées et considérées comme susceptibles de par leur valeur probatoire ou informationnelle:
- de justifier les dépenses continues importantes consenties pour conserver des support fragiles de façon permanente,
- d'intéresser la communauté internationale des chercheurs.

Le rôle traditionnel dévolu aux archives historiques est de traiter les documents sélectionnés dans le but d'en faciliter l'accès à la recherche et de les conditionner pour une préservation permanente. S'y ajoute le rôle de conseil ou d'assistance dans le processus de sélection des archives définitives par l'organisme déposant.

Ceci implique, dans le cas des Archives historiques de Florence, trois types de tâches complexes – dont les caractéristiques peuvent être synthétisées comme suit:
- établissement d'un plan de classement ('classification scheme'): système numérique hiérarchisé qui en replaçant chaque document dans le contexte interrelationnel de l'entité productrice en éclaire le rôle et la fonction;
- analyse dossier par dossier: les archives dédient une attention particulière à l'élaboration de 'finding aids' détaillés permettant la recherche ('retrieval') la plus aisée possible.

Chaque dossier est décrit, doté d'une cote d'archive permettant de l'identifier, d'un titre indiquant l'argument ou la transaction concerné, d'un abstract en définissant la nature et en synthétisant le contenu.

Les inventaires et index ainsi constitués font l'objet d'une saisie informatique qui les rend cumulatifs et 'updatables' à volonté, interrogeables aisément à travers le plan de classement, un thesaurus de mots-clés mais aussi un 'retrieval' 'free text'. La banque de données est diffusée télématiquement par le truchement du serveur communautaire ECHO à Luxembourg, ce qui la rend accessible à la communauté internationale de la recherche.

Le conditionnement des dossiers
Les dossiers, débarrassés préalablement des pièces métalliques susceptibles de provoquer leur dégradation, sont placés dans des boîtes de carton 'acid-free' avant d'être stockés en magasins dotés de l'air conditionné et de systèmes anti-incendie et anti-vol sophistiqués.

Le dépôt bénéficie du privilège d'exterritorialité et de la garantie de l'Etat italien.

Situation actuelle et le Groupe de travail

Le contrat de dépôt a constitué un ballon d'oxygène mais le système comportait de nombreuses faiblesses. Les premiers envois ont fait apparaître que:

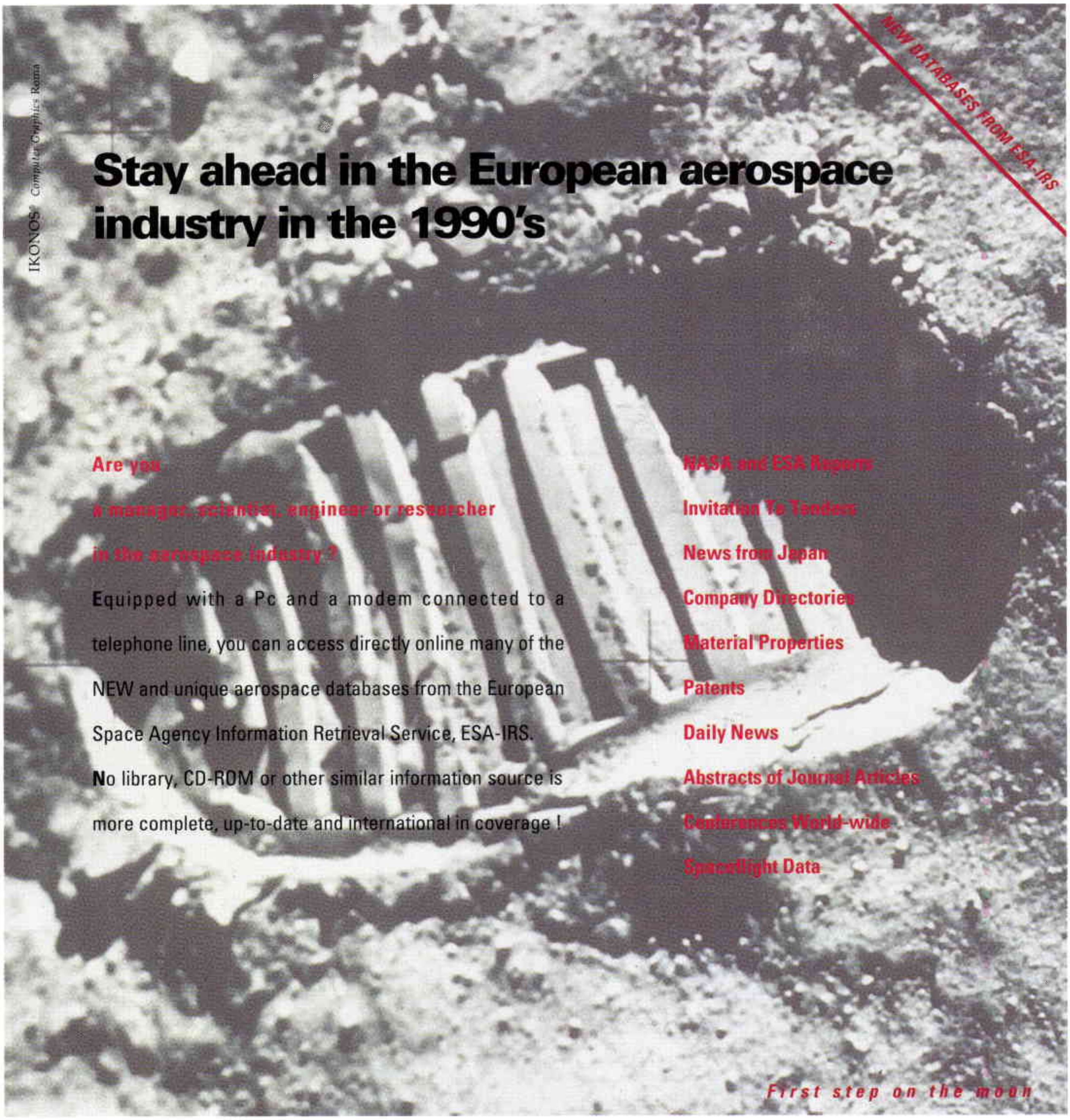
(a) Les dossiers 'archivés' n'étaient pas répertoriés correctement et l'on n'en connaissait même pas le volume exact.
(b) Ils contenaient l'intégralité de ce qui avait été mis dans une chemise, y compris des documents sans intérêt et les archives étaient inutilement redondantes.
(c) Ils ne portaient aucune mention de la durée pendant laquelle il fallait les conserver.
(d) Aucune indication n'était donnée sur le lieu où archiver tel ou tel dossier (à savoir archives locales, Florence ou ailleurs). Un pré-tri semblait nécessaire avant envoi à Florence.

Il a été demandé au Groupe de travail constitué par le Directeur général de passer en revue ce système. Il entreprendra l'inspection des archives situées dans les locaux de l'ESA et étudiera la question du transfert des documents archivés à Florence mais sa principale responsabilité consiste à définir les règles et directives afin de déterminer quels éléments de documentation présentent de l'importance ou de l'intérêt pour l'Agence et pour combien de temps.

Le volume de documents et de dossiers archivés est en progression constante. Par conséquent, l'espace étant limité, il faut veiller à ce que les rayonnages disponibles ne contiennent que des documents de valeur. Des règles simples de tri des documents devraient être élaborées en collaboration avec le personnel compétent. En ce qui concerne notamment la documentation technique, il faudra s'assurer le concours des techniciens et membres des équipes de projet.

Enfin, il faut étudier avec attention la question du personnel. L'expérience prouve que l'on prête d'ordinaire peut d'attention, voire aucune, à l'archivage. Cependant, si l'Agence souhaite conserver l'historique exhaustif et cependant concis de ses activités et réalisations antérieures, il faut non seulement adopter une méthode cohérente et professionnelle mais encore engager des experts qualifiés, des archivistes formés à cette tâche, pour s'en occuper. Faute de quoi la question se reposera avec plus d'acuité avec le risque de devoir détruire de la documentation de grande valeur.

L'Agence est arrivée à un âge auquel pour travailler il lui faut se souvenir de son passé, y avoir accès. Un effort est à faire, cet effort implique la participation de spécialistes. Mais son bénéfice sera sans commune mesure avec son coût.


IKONOS Computer Graphics Roma
NEW DATABASES FROM ESA-IRS
Stay ahead in the European aerospace industry in the 1990's
Are you
a manager, scientist, engineer or researcher
in the aerospace industry ?
Equipped with a Pc and a modem connected to a telephone line, you can access directly online many of the NEW and unique aerospace databases from the European Space Agency Information Retrieval Service, ESA-IRS.
No library, CD-ROM or other similar information source is more complete, up-to-date and international in coverage !
NASA and ESA Reports
Invitation To Tenders
News from Japan
Company Directories
Material Properties
Patents
Daily News
Abstracts of Journal Articles
Conferences World-wide
Spaceflight Data
First step on the moon

The European Space Information System – Approaching Pilot-Project Evaluation

A. Ciarlo, S. Ansari, P. Donzelli, P. Giommi, P. Regner, H. Stokke, P. Torrente & S. Walker

ESIS Project, ESRIN, Frascati, Italy

After several years in development, ESIS, the European Space Information System, is approaching the day of reckoning: an evaluation, carried out largely by users, of the results achieved in the course of the Pilot Project, and of the benefits provided to the scientific community by the European Space Information System's services is getting under way. This article provides an overview of ESIS's evolution and the services it supports, as well as some ideas for its possible future development.

Background

The ESIS Pilot Project started with the approval by ESA's Science Programme Committee (SPC) and the ESA Council in November 1987 of a proposal prepared after preliminary studies and dialogue with the prospective user community. This proposal was based on a two-stage approach, a Pilot Project followed by a full Development Programme, the latter to be designed and approved on the basis of the experience gained through the pilot study. The evaluation exercise that is currently beginning is intended to collect and assess all the relevant aspects of this experience.

The prime objective of ESIS was – and still is – to simplify the exploitation and application of scientific data stored in a number of electronic archives by scientists involved in space research. This goal was to be achieved by the provision of both a uniform interface to all archives, and of tools to make a preliminary analysis of the data retrieved. The ESIS Pilot Project addressed the needs of two particular disciplines within the space sciences, namely Astronomy & Astrophysics and Space Physics. Extensions to other disciplines (i.e. microgravity and Earth observation) were to be foreseen in the design, but not implemented.

Evolution of the project

The first implementation of ESIS, as approved by Council, included the integration with ESIS of the following archives:

- IUE: data collected by the International Ultraviolet Explorer satellite, and stored at VILSPA, in Villafranca (E)
- Exosat: data collected by the Agency's X-ray astronomy satellite, and stored at ESTEC, in Noordwijk (NL)
- the Space Telescope archive, located at the European Space-Telescope Facility (ST-ECF), in Garching (D)
- the SIMBAD database of astronomical objects, held at the Centre de Donnees Stellaires, in Strasbourg (F)
- AMPTE-UKS and AMPTE-IRM databases, containing data on the plasma-physics experiments carried out by the two AMPTE satellites, stored at the Geophysical Data Facility of the Rutherford-Appleton Laboratory (UK)
- the Information Retrial Service at ESRIN, in Frascati (I), containing a large amount of bibliographic data.

A basic assumption of the Pilot Project was that all data were to remain at the institutes that created the archives, to avoid the risk of scientific 'obsolescence' of the data when removed from the associated scientific expertise.

Initially, the whole project was heavily biased towards network-connectivity issues, since the existence of a network was an obvious pre-requisite for the system, and a clear user need for improved network connectivity was emerging. At the same time, with the aim of simplifying integration of other archives in the future, great reliance was placed on the appearance on the market of ISO/OSI-compliant network communication software.

A preliminary architecture for the whole system, structured in 'layers', included the following:

- a backbone network
- a Pilot Distributed System (PDS), meant to provide higher-level network services

Figure 1. ESIS backbone network and databases

(layers 4 to 6/7 of the ISO/OSI models)

- a Query Environment (QE), with the function of providing the user with a single homogeneous view of all of the databases integrated with ESIS
- a Correlation Environment (CE), intended to supply the data-manipulation services required to display and inspect the data retrieved by the query environment.

For each of these layers, a set of system requirements was defined and confirmed with prospective users at two Workshops which took place at ESRIN in the autumns of 1987 and 1988, respectively.

In the course of the project, a certain number of changes took place in ESA, in the scientific community, and in industry that affected the conversion of the initial concept into the practical system. The activities started later in the Pilot Project were naturally more easily adapted to the then current situation, while the very early ones were critically affected. The main changes occurred in the following areas:

- In response to a growing user need, provision of network services was progressively rationalised in ESA and connectivity became of lower priority for ESIS.
- The standard OSI products promised by software suppliers for several years failed to materialise, except for the mail (X.400) and related (conference, bulletin board, etc.) products. This was very much in contradiction with expectations at the time of the ESIS Pilot Project's definition, and had a severe impact on the ESIS implementation.
- At the beginning of the Pilot Project there was a very marked preference in the scientific community for VAX/VMS computing environments; this resulted also in the ESIS/SPAN union. Since 1990, however, there has been an increasing trend toward UNIX and TCP/IP.
- The homogeneous and integrated access to multiple archives requires simultaneous searches on remote databases. This is possible in principle, but some prototyping activities have shown that it would lead to absolutely unacceptable response times. A review of the architecture resulted in the introduction of a centralised ESIS catalogue, called 'Cats&Logs', which is essentially a copy of those at the remote database sites. This requires copying at the central site of only the catalogues, whilst the data itself (i.e. images, spectra, etc.) remains in the original archive.

While these changes are significant from the software-architecture viewpoint, they only affect the relationship between ESIS and the various databases involved, leaving the initial goals of the system untouched from the user's viewpoint.

Today's status

Current services

Although the main ESIS services, Query Environment (QE) and Correlation Environment (CE), are only now being gradually opened up to users, a certain number of services have already been provided for some time to the user community via the ESIS public account, which is reachable from the SPAN, Internet and public networks. The account provides access to directory services such as the StarWays database (see accompanying panel) and the online version of the World E-Mail Directory by Benn & Martin. A simple interface to ESIS Cats&Logs (see accompanying panel) allows the user to search for objects in more than thirty astronomical catalogues and mission logs, using either coordinates or object identifiers. All of the basic search functions are available, such as search in a cone, search in a box, search nearest and search by name. The last of these exploits a copy of the SIMBAD database installed at ESRIN as name server, anticipating one of the core functions of the ESIS Query Environment.

It is also possible to view a number of bulletin boards, such as 'Astronews' (ESTEC), which provides information about space astronomical projects, and the Hubble Space Telescope Bulletin Board run by the ST European Coordination Facility. The Meudon Solar Activity Bulletin, which provides a daily selection of data and indices on the Sun and on geomagnetism, has recently been added to the services available via ESIS.

Moreover, the public account gives 'native access' (without modifying the user interface) to the Pilot Project archives already mentioned – STARCAT, EXOSAT, SIMBAD, IUE, ESA-QUEST, GDF – as well as to several other ESA information services, such as the Space Environment Information System (ESTEC) and the ESA Prototype International Directory (ESRIN). A local (ESRIN) copy of the Browse software developed at the Exosat Observatory is also accessible via the public account. Some facilities supporting the exchange of information between users are also provided (not all with full functionality), such as electronic conferences, mail gateways (EARN/BINET, JANET,SPAN,X.400), remote login (to SPAN, JANET and Internet).

The Query Environment

The ESIS Query Environment (QE) is the tool for overcoming the problems stemming from the heterogeneity of the data archives: the ESIS QE will make them appear to the users as a single, homogeneous database, while at the same time the archive administrators will continue to operate on their 'own' system. Apart from space-mission data archives such as ST-ECF, IUE-VILSPA, Exosat and AMPTE-UKS, the QE will also provide access to astronomical catalogues, bibliographical files, directories of public-domain software, scientists' electronic-mail (e-mail) addresses, StarWays (see box), etc.

The ESIS QE implements a generic means of dealing with any kind of data source by means of data models (logical descriptions of the data available through the system), thereby ensuring openness towards new databases. A complete user-oriented query language is available to users, giving them the full freedom to search for, and combine, any information items described in the data models. Currently, the main means of user interaction with the QE is via menus, but an easy-to-use graphical interface is also being designed to simplify the use of the system still further.

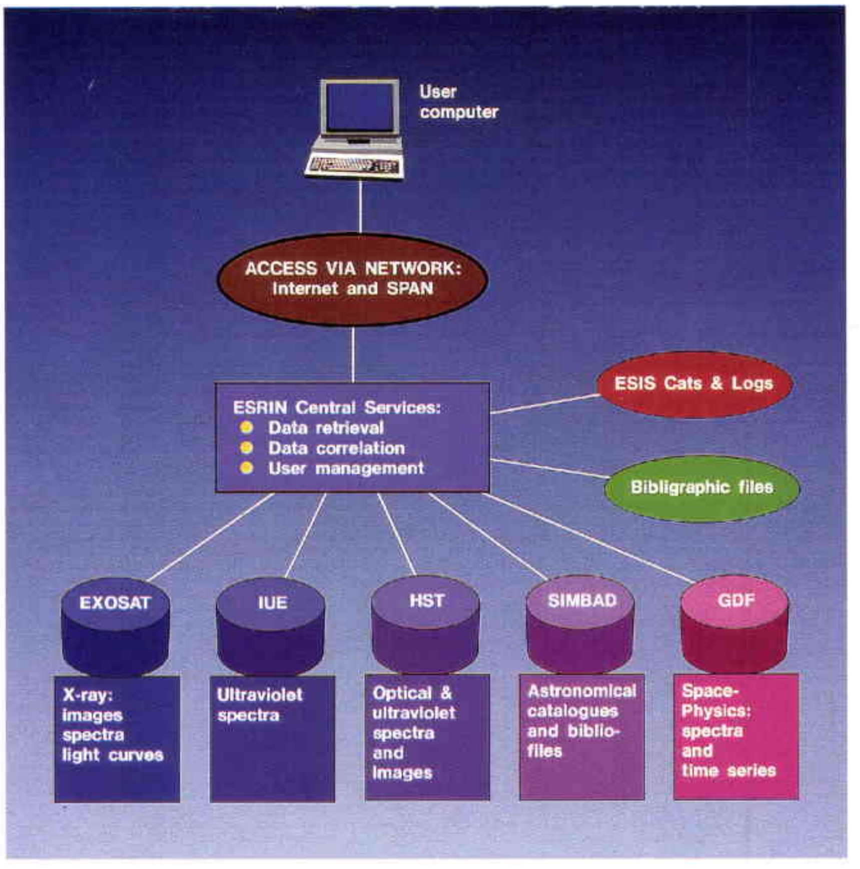


Figure 2. ESIS abstract architecture

StarWays

Being the most comprehensive database of its kind, StarWays offers continuously updated information on associations, societies, scientific committees, agencies, companies, institutions, universities and, more generally, on organisations involved in astronomy and space sciences. To date, about 6000 entries from about 120 countries are accessible. All data have been compiled by Observatoire Astronomique de Strasbourg (A. Heck), France, and published previously under the acronyms IDAAS, IDPAI and ASpScROW. The next paper edition will be published this year by André Heck under the title 'StarGuides'.

The information available on line is structured for easy and direct access. Many practical data are available concerning the organisations listed: postal and electronic-mail addresses; telephone, telex and telefax numbers; year of foundation; numbers of members/staff; main activities; titles, frequencies, ISSN numbers and circulations of periodicals produced; names and geographical coordinates of observing sites; names of planetariums; awards, prizes or distinctions granted; and so on.

StarWays is accessible free of charge via the ESIS public account. The successive menus are self-explanatory. Online tutorials and presentations are also available, as well as a dedicated mailbox system. Eventually, StarWays data will also be available via the ESIS Query Environment.

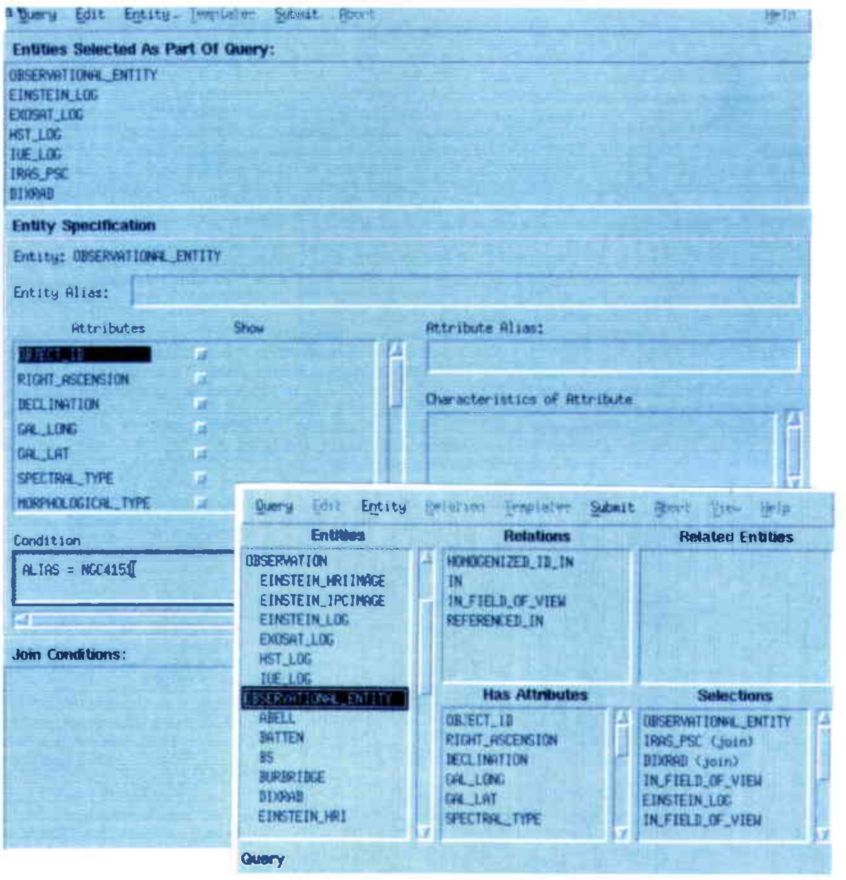


Figure 3. A sample query for the AQL semantic network

ESIS Cats&Logs

Cats&Logs is a database containing astronomy-mission logs and catalogues. It was set up by ESIS/ESRIN to correct a performance problem that was identified in the first concept of the QE architecture. It will allow the Query Environment to perform complex query and join operations quickly on catalogues and mission logs, as well as facilitate all kinds of catalogue queries, even when the data are stored at different, remote locations.

Cats&Logs is being 'populated' according to requests from the user community and currently holds more than 30 catalogues covering all wavelength regions and mission logs (at present the HST, IUE, Exosat, and Einstein missions). For the ongoing missions, e.g. HST and IUE, Cats&Logs is being updated on a regular basis in consultation with the data providers.

Cats&Logs provides optimised access for coordinate searches with functions such as 'search in a cone', 'search in a box', and 'search nearest', as well as fuzzy joins on coordinates. All coordinates have been put into a consistent format (J2000.0), and other fields (date, time, names, etc.) have been standardised. By so doing, queries like 'List all observations of a certain object in all wavelength regions!', or 'Which objects have been observed both by HST and Exosat?', can easily be answered.

The Cats&Logs database, implemented as an Oracle relational database, has proved to perform very efficiently, providing fast and accurate data access. It can currently also be accessed through a simple interface from the ESIS public account, allowing users to provide their comments and suggestions at an early stage.

Briefly, the Query Environment works as follows. The user request, once formulated on the user's computer, is automatically transmitted to a central server at ESRIN that interprets it and locates the data with the Cats&Logs database. The requisite number of 'elementary' queries, which can be understood by the remote databases containing the data, are then generated and each sent to the relevant database. The central server then collects the results coming from the various archives, combines them and puts the data into a consistent format. The combined result is then presented to the user. This result is also usable as input for further and repeated refinement of the query, or as input to the Correlation Environment (see next section).

In this way, a common and uniform access mechanism is provided to data systems which would otherwise require different access methods. The user has therefore to learn only one access system rather than a myriad of methods.

The Correlation Environment

The data retrieved from the Query Environment often need to be manipulated scientifically or compared with other data. The Correlation Environment (CE) is the component of ESIS that performs these functions. The CE provides the tools needed to display, manipulate and compare multi-mission data.

The CE is not intended for the detailed analysis of archived data, but rather to provide the users with a tool for meaningfully comparing all of the data retrieved from the remote archives. In other words, the CE provides a 'wide-angle' view of multi-experiment data. Detailed analysis can only be conducted with more specialised software usually only available from the institutes that produced the original data.

A first step has been taken in creating such an environment, and a prototype is being developed at ESRIN by the ESIS staff in collaboration with programmers from industry. The prototype, called 'SPACE' (Space Physics and Astronomy Correlation Environment), makes use of in-house-developed software and of public-domain packages developed in a number of scientific institutes.

SPACE can be accessed through a graphical user interface, based on OSF Motif, and supports both astronomy and space-physics functions. The astronomy version of SPACE includes several routines for the manipulation of images, spectra and time-series. Images from Exosat, the Hubble Space Telescope and Einstein, for instance, (and other satellites in the future) can be compared to study the spatial structure of astronomical objects at different frequencies or at different times. The spectral manipulation package can display spectral data from different detectors like those on board IUE and Exosat. The time-analysis package supports the investigation of the time variability of astronomical objects as well as events of space-physics interest. A basic statistical-analysis software package is also under development.

The space-physics version of SPACE allows the user to perform all the basic data manipulation and visualisation needed in this field. Examples of the functions provided are capabilities for generating spectrograms, multi-panel plotting, hodograms, etc.

The development of SPACE was started about one year ago. Some parts of the prototype are now ready and have been demonstrated at a number of conferences. Examples of the results that can be obtained with the system are shown in some of the figures accompanying this article.

It is anticipated that as the availability of archival information increases, tools for correlating data from different experiments will play an increasingly important role. Development of the Correlation Environment is therefore foreseen as an ongoing ESIS activity, providing more and more functionality as ESIS matures in the future.

Evaluation

The ESIS project was structured from its inception into two stages: a Pilot Project, and a full operational implementation, also referred to as the 'ESIS Programme'. The main objective of the evaluation process is thus the summing up of the experience of the Pilot Project to provide well-founded guidelines as to how the Pilot Project system should evolve into the full implementation. These guidelines will provide the basis for the preparation of a proposal for an operational ESIS Programme, to be submitted for approval by the ESA Council in the second half of 1993.

The ESIS evaluation will be carried out from two main viewpoints: scientific and technical. The first is the primarily the users' viewpoint and will assess to what extent ESIS, in its Pilot Project implementation, satisfies the needs of the scientific community. The second will evaluate how technically sound the solutions adopted are, given the wisdom of afterthought.

The technical evaluation is to be carried out by ESIS staff and will take place in parallel with the scientific evaluation.

End-user appraisal

As for any information system, the involvement of the end users during the development phase is a prerequisite for the success of the project. In this context, the evaluation of the first versions of the system by the users is a critical process that must be properly organised in order to derive maximum benefit from the users' feedback on the project.

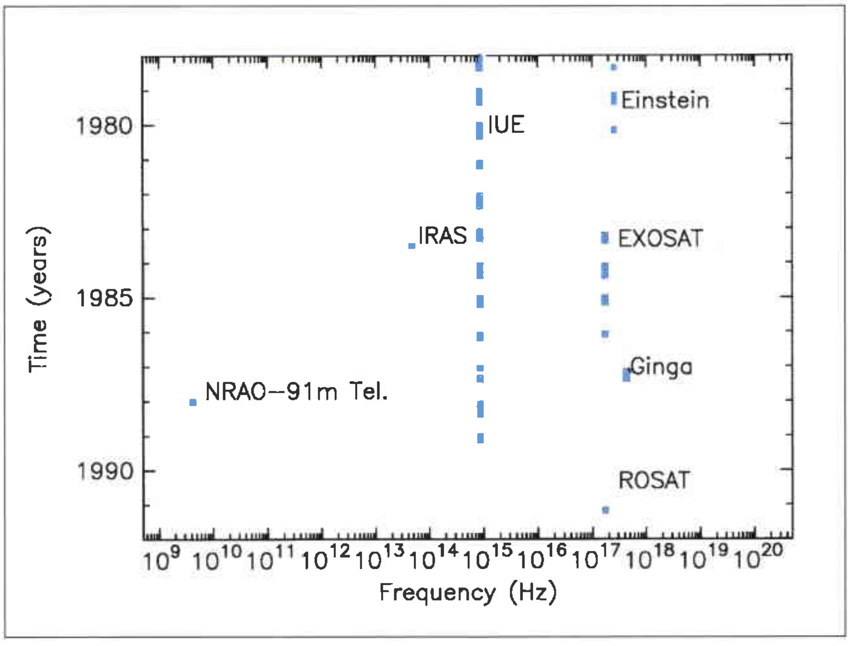


Figure 4. General overview of data available within ESIS for the Active Galaxy NGC4151. Observation time is plotted as a function of approximate frequency at which the measurements were made; this allows the user to select simultaneous multi-frequency data sets

For this purpose, a set of evaluation criteria have been identified in parallel with a collection of test scenarios. These scenarios, representing what are considered 'typical' data search cases, have been converted into repeatable tests. These will form the common core of the scientific evaluation and may be employed by the users as guideline for the execution of their own tests.

The evaluation criteria constitute the framework for the preparation of questionnaires that will be distributed to the users to gather the results of their evaluation, their comments and suggestions. These criteria cover such aspects as:

- homogeneous access to data
- relative merits of interaction paradigms (query by menu; query by diagram)
- extension of data scope

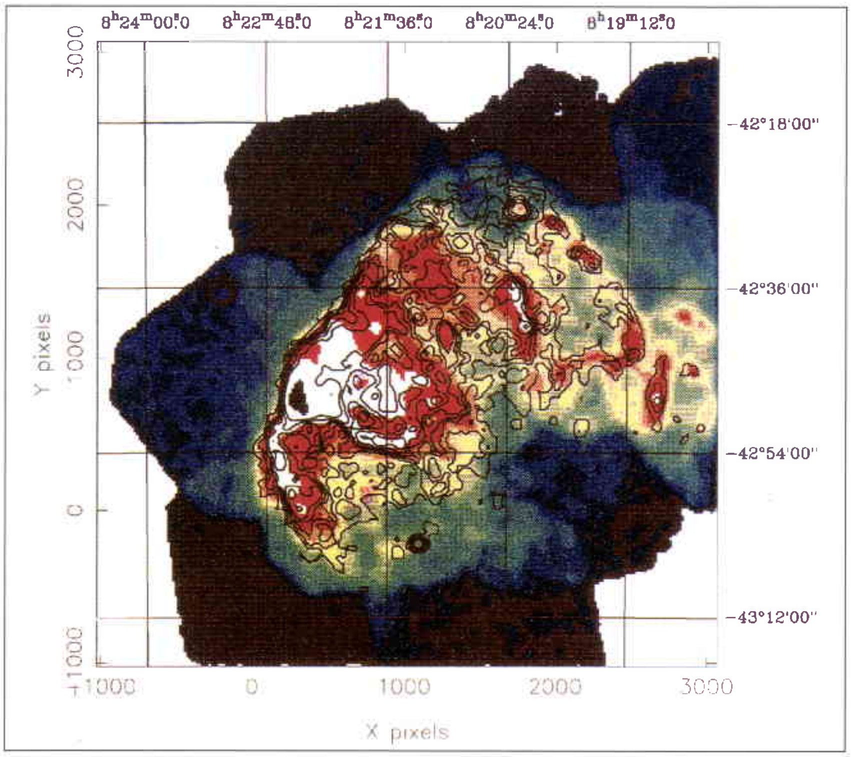


Figure 5. Mosaic including several X-ray images of the Supernova Remnant Puppis-A obtained with the Einstein satellite. Iso-intensity contours of a similar image produced by ESA's Exosat X-ray astronomy satellite have been superimposed

- completeness and quality of scientific functions (correlation environment)
- difficulty of use and learning versus power
- performance.

The evaluation of ESIS by the users has been arranged in two steps according to the delivery of two main versions of the system. The first version – a sort of beta release – will be the subject of a 'restricted' evaluation, i.e. one carried out by the ESIS team and by a small group of users. During this restricted evaluation there will be no distribution of ESIS client software to remote users. A public account, accessible from graphics terminals will be set up instead to allow remote users also to access the system and to provide comments.

For the second step in the evaluation, the 'public evaluation', the first complete operational release of the system will be available. This evaluation will be carried out by all (willing) users, who will be asked to report their impressions, suggestions, etc. by completing a small questionnaire. They will also be provided with the test scenarios as both an example and a reference for the use of the system.

The public evaluation of the ESIS pilot system will be 'officially' opened at a hands-on Workshop, to be held at ESRIN in early 1993 (dates and registration information are to be found in the ESIS Public Account; see panel at end of article). During this Workshop, the users will be guided through some typical applications of the functions provided by the system and their first reactions collected in preparation for future developments and improvements.

Technical assessment/testing

Testing of the overall ESIS system is an essential part of its development; it is the process of exercising the system, demonstrating its performance, and assessing its overall quality, where the basic definition of quality is that 'the product meets the needs of the users', and secondly that 'the system conforms to its specifications'.

However, in addition to the conventional testing and final acceptance of the system software, as foreseen in the ESA Software Standards, it has been considered necessary to carry out a more general technical evaluation of the whole system. This decision was driven by three main considerations:

(a) ESIS is more than a software system, the software being just one of its components. System operators (i.e. scientists and engineers responsible for operating the system and supporting the users), the telecommunications infrastructure, and hardware are the other components. Each plays a fundamental role in determining the quality of the overall service provided to the users.

(b) The Pilot Project has evolved in a very rapidly changing technological environment, where some technologies that appeared very promising a few years ago (e.g. ISO/OSI products) are still not in place, while others (e.g. Internet, optical disks, Motif, etc.) have very quickly become de-facto standards.

(c) The role of the ESIS implementation in the Pilot Project with respect to future developments.

A specific technical evaluation process was therefore devised with the aims of:

(i) reviewing the validity of the design assumptions with respect to the current state of the art of information technology, and its expected trends in the medium term;

(ii) assessing the validity of the solutions that have been implemented, their quality and performance and their reusability during the operational phase;

(iii) providing a reliable technical baseline for estimating the costs of the ESIS operational phase (operations, maintenance, upgrading, etc.).

As in the case of the scientific evaluation, a set of project-specific criteria has been identified which include:

1. Choice of hardware/software infrastructure: the infrastructure will have to be evaluated in terms of network bandwidth and topology, access points and backbone node performances, Oracle RDBMS performance and suitability for handling scientific databases. The infrastructure set up for the Pilot Phase relies on VAX-DECnet (version IV). This choice will have to be confirmed with respect to other platforms (Unix) and protocols (TCP/IP and OSI) and the evolution of SPAN in Europe.
2. Choice of user hardware/software: VMS and Unix graphics workstations (OSF/Motif required) are presently supported. The access protocols supported are DECnet (European SPAN) and TCP/IP (Internet). These choices will have to be confirmed taking into account the costs of maintaining multiple versions, some of which could be rapidly abandoned by the users (e.g. migration of users from VMS to Unix), or not used at all due to their low performance vis-a-vis the ESIS requisites (e.g. character terminals).
3. Principle of distribution versus centralisation of services and data: the question of centralisation versus distribution of the scientific archives has been one of the basic themes of the ESIS project rationale. Maintaining archive decentralisation was assumed as a boundary condition for the Pilot Project, with the precise aim of confirming or modifying such an approach on the basis of the experience gained during the pilot activities. During the Pilot Phase, the approach taken with respect to centralisation versus distribution has mainly consisted of the centralisation of the system Access Point and of the Astronomy Catalogues and Mission Logs (grouped and normalised in the Cats&Logs database at ESRIN). The technical evaluation of these choices will assess their suitability for a long-term operational environment.
4. Principle of data distribution: the data distribution through ESIS follows the constraints and heterogeneity imposed by the archives. Catalogues, mission logs, data descriptors and bibliographic references are all available online, while scientific data are, in some cases, only available offline, either via networks or other media. This situation will have to be reviewed taking into account: the limits imposed on ESIS's potential to extract data; the growth in data availability foreseen for the next decade and the evolution in mass-storage technology versus network capacity; and the need for co-location of scientific data and scientific expertise.

As in the case of the scientific evaluation, the set of test scenarios will be used as a reference.

The ESIS Steering Committee – nominated at the outset of the project as an independent body of user representatives to monitor and advise the project – is playing an active role also during the ESIS evaluation. The Steering Committee has in fact been involved in the provision of the scientific test scenarios and will perform an independent evaluation

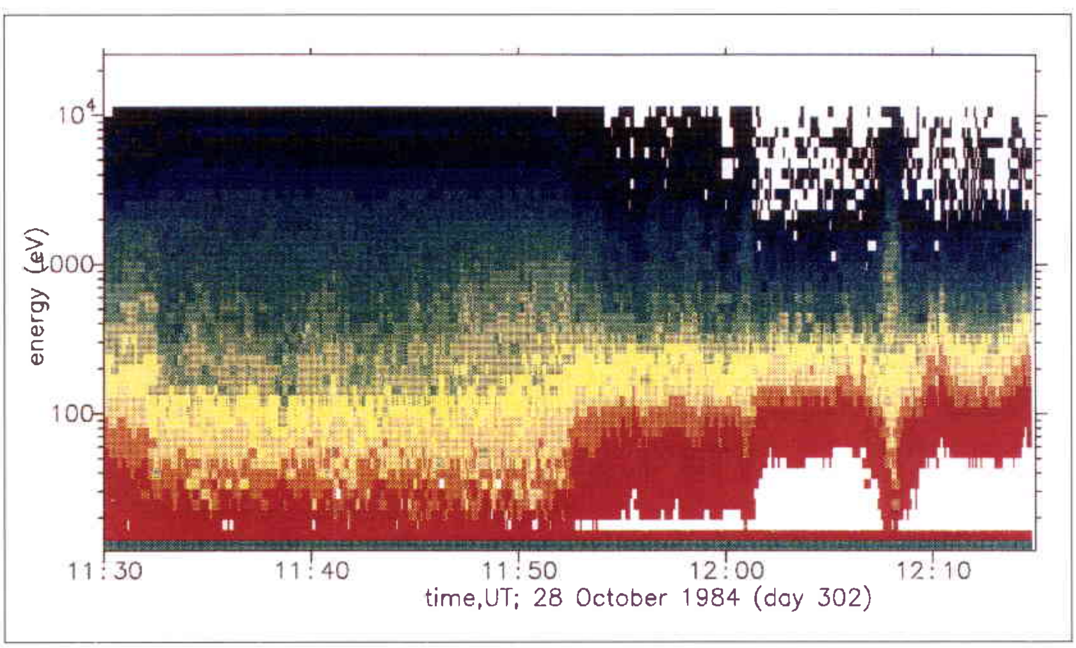


Figure 6. Spectrogram of electron intensities measured by the AMPTE-UKS satellite on 28 October 1984, whilst travelling through Earth's magnetosphere towards the magnetosheath. The separating boundary between the two, the 'magnetopause', was crossed at approximately 12:00 UT

of the system, covering both technical and scientific aspects. The Committee will also review the results of the evaluation activities performed by the end users and by the project team.

The future

Towards more-standard data systems

ESIS was established to provide the scientific community with a tool that provides uniform access to archives that are similar in the services they offer, but are only accessible through very different languages. This has been accomplished by providing a system that handles all the differences between the various data archives on the user's behalf. One obvious extension of ESIS after the Pilot Project will be the integration of additional archives. For the development of future archives, however, it is advisable to minimise heterogeneity in data formats, retrieval systems and user interfaces. This will make the data more easily accessible, both to users or to computer software, and will reduce the development costs of new archives. This saving can be accomplished only through coordination, and by the definition of sound and widely accepted guidelines for the development of new archives.

During the ESA Science Programme Committee (SPC) meeting last April it was suggested that ESIS should play a role in this field, and similar suggestions have been received from a number of archival centres. In the future, therefore, ESIS could also serve as a model for the design of archives for data produced both by ESA missions and by national programmes.

Historical archives at ESRIN

A scientific archive goes through a number of phases during it lifetime. These include an active phase covering the period when the data are being acquired, calibrated and processed, and a historical phase that is reached when the data are stable and fully understood, and the team of specialists that produced the archive moves on to other projects.

During the SPC meeting in Capri it was also suggested that ESIS/ESRIN could be the site at which all historical archives are stored and maintained after the completion of the mission. There are already some scientific archives within ESA that have reached this phase, namely the Cos-B and Exosat archives. ESIS is already engaged in setting up a long-term optical-disk archive of all the original Exosat tapes and of the software necessary to read and manipulate the data*. The experience and the infrastructure developed in the course of this activity can be fairly easily applied to other archives, and the intention is to continue with this exercise and to store more historical archives at ESRIN as they become available.

* More than 3000 Exosat tapes have been copied to date to the archive and are already available to the scientific community. The remaining data will be incorporated in the next few months.

Conclusions

The recent rapid expansion of electronic archives for scientific data makes the need for a system like ESIS even more acute now than when the idea was first put forward several years ago. After a considerable amount of development, ESIS is now gradually being released to the user communities. Their reactions will be the real 'result' of the Pilot Project, and will establish to what extent ESIS fulfils their needs. This feedback from the users will be the essential basis upon which the future shape of ESIS will be decided.

How to Access ESIS

The user platforms supported during the Pilot Project are:

- VAX/VMS graphics workstations (OSF/Motif required) connected to ESRIN via DECnet
- Sun/UNIX workstations (OSF/Motif required) connected to ESRIN via TCP/IP on Internet.
- VAX/VMS computers, with ANSI terminals (limited functions only), connected to ESRIN via DECnet.

The ESIS Public Account can be accessed through:

- SPAN: $ set host ESIS (29617)*
- INTERNET: % telnet esis.esrin.esa.it (192.106.252.127)*

* User name ESIS, no password

Satellite Control Throughout The Complete Lifecycle

J.T. Garner
Communications Satellites Department, ESA Directorate of Telecommunications Programmes, ESTEC, Noordwijk, The Netherlands

A. Ross
Logica Space and Communications Ltd, Leatherhead, United Kingdom

Satellite control is a common factor between the pre- and post-launch environments: in the pre-launch phase the major activities are the control and testing of the satellite, while in the post-launch phase the major activities are the control and use of the satellite. ESA has conducted a study of the operational lifecycle of commercial communication satellites. The study recommends a more harmonised approach to satellite control through the standardisation of technologies and methodologies.

Historical background

For each of the scientific and applications satellites that it has constructed and operated, the European Space Agency (ESA) has used control systems both before and after the launch. In the early days of European space exploration ventures, a scientific satellite was taken to the post-launch control centre before its launch to undergo compatibility testing. A successful compatibility test was required before a launch go-ahead was given. Before ESA launched application satellites, it was not unusual for two sets of Electrical Ground-Support Equipment (EGSE) to be deployed at the launch site, with one being an on-line back-up for the other. As European experience in space exploration and exploitation increased, back-up EGSE was no longer set up at the launch site.

The first application satellite that was produced and operated under the auspices of ESA was part of a communications development programme. The satellite, called the Orbital Test Satellite (OTS), formed the space segment of the communications system and was successfully launched in May 1978. For this communications programme, the pre-launch EGSE was located at Cape Canaveral, in Florida. It consisted of Overall Check-Out Equipment (OCOE) and the necessary Specific Check-Out Equipment (SCOE). The post-launch Operations & Control Centre (OCC) was located at ESOC in Darmstadt, Germany. It performed all activities associated with post-launch operations, from when the satellite separated from the launch vehicle until the satellite's end-of-life in orbit more than twelve years later. The computer software for satellite post-launch control underwent compatibility testing without the OTS being transported to Darmstadt: satellite telemetry (TM) and telecommands (TC) were relayed over the public telephone network to and from the OCC at ESOC via the OCOE. The OCOE retained its executive role until the launch.

The architecture of the system for satellite control during OCC software compatibility testing is shown in Figure 1. This methodology has been used in each of ESA's communication satellite programmes, which include eight successful launches, with the launch of Olympus-1 in July 1989 being the most recent. The Special Check-Out Equipment (SCOE) shown in Figure 1 interfaces satellite telemetry (TM) and telecommand (TC) signals at baseband or radio frequencies. Most often baseband TM and TC signal links to and from the satellite are made using hardware umbilical connections. The SCOE can also provide electrical power and specific test signals to the satellite. The SCOE is normally operated under the control of the OCOE during OCC compatibility testing and when specific tests associated with an on-board satellite subsystem are undertaken.

On the ESA programmes that have produced geostationary communication satellites, the satellite's complete lifecycle starts at least 12 months before the launch. An OCOE is the executive centre used for satellite control during integration and system-level testing, which includes simulations of the vibrations associated with the launch vehicle operations and of the post-launch environment (thermal vacuum). The OCOE is deployed at the launch site for final satellite testing and

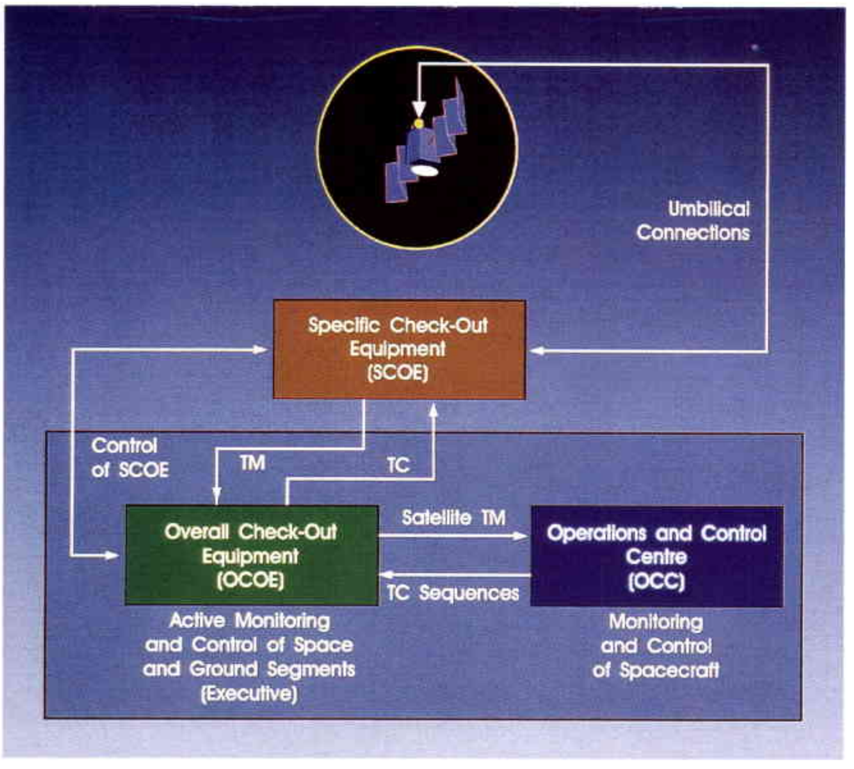
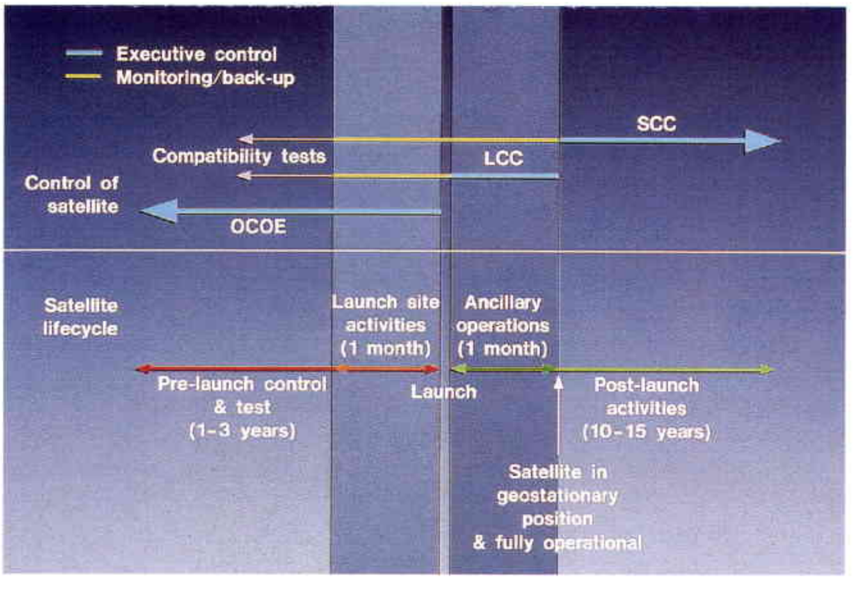


Figure 1. Configuration for pre-launch OCC software compatibility testing

Figure 2. Control centre utilisation throughout the satellite lifecycle



preparation for launch, including testing of satellite and launch vehicle compatibility. The OCOE computer software, which monitors the satellite's health, gives an important input for go-ahead during the launch countdown.

After launch, the OCOE hands the control of the satellite over to an OCC for all activities until the satellite's end-of-life in orbit. The post-launch OCC activities begin in earnest at satellite launch vehicle separation, and include important early orbit tasks, such as the firing of a rocket motor, which is an integral part of the satellite, to achieve a geostationary position for normal operational life. When the geostationary position has been achieved and the satellite's communications payloads have been commissioned, the satellite's full working life begins. It can last more than 10 years.

In summary, the complete operational lifecycle of a communication satellite involves pre-launch control and testing, and post-launch control and use. Satellite control is a common factor between the pre- and post-launch environments.

Study findings

This historical background formed the baseline for a recent ESA study of the operational lifecycle of commercial communications satellites, which was conducted by Logica Space and Communications Ltd. (UK).

The study found that, for commercial communications satellites, it was common for three control centres to be employed during the satellite's operational lifecycle. These control centres and their uses (Fig. 2) are:

1. The *Overall Check-Out Equipment (OCOE),* used for pre-launch control and testing activities including executive control of the satellite during launch vehicle countdown.

2. The *Launch and Early Orbit Operations and Control Centre (LCC),* used to monitor the satellite during launch vehicle countdown and then as executive control to place the satellite in the required geostationary position. These activities are sometimes called ancillary but they are vital to achieving a fully operational status.

3. The *Satellite's Nominal Control Centre (SCC),* used to control the satellite after it has been placed in the geostationary position, to ensure that user needs are met.

The study noted that responsibility for satellite control during the different phases of the lifecycle is often divided between different organisations. There are intrinsic similarities for satellite control via telemetry and telecommand between lifecycle phases. However, these similarities are not fully exploited at present, as the organisations responsible for each phase of the satellite lifecycle typically use different satellite control software and procedures. Consequently, there is a greater emphasis on the re-use of facilities between satellite programmes than on achieving commonality between the phases of a single mission. This can be considered to be a 'horizontal harmonisation' and re-use of facilities, which in itself is commendable. However, re-use could be extended if commonality between phases of a single mission was introduced. If such a 'vertical harmonisation' was combined with the horizontal harmonisation, a better overall result could be attained. The standardisation of technologies and methodologies for control centres and the resulting reduction in duplication between control centres, could promote such an all-round solution, and could diminish the risk of operational problems and reduce costs. Given the constraints imposed by the established contractual conditions, the study has identified the key importance of information transfer between lifecycle phases. The study recommends greater standardisation of computer data bases of telemetry and telecommand characteristics and of satellite documentation.

The findings of this study, which has considered only the commercial satellite environment, are in keeping with the findings of the ESA Committee for Operations and Electrical Ground Support Equipment (EGSE) Standardisation (COES).

Possible improvements
The study proposes a possible move towards harmonisation of post-launch OCCs. This solution is illustrated in Figure 3. It shows that, after launch vehicle lift-off, the SCC always has executive control of the satellite. During the launch and early orbit phase, the primary technical expertise would be located at the LCC. When the satellite has been placed in its final geostationary position, the roles could be reversed, with the LCC being a back-up to the SCC for a limited period, if necessary. However, throughout operations, the SCC would audit the telecommands requested by the LCC before transmission. This methodology is similar to the pre-launch compatibility testing of post-launch satellite control centres, which is performed to obtain a launch go-ahead. The similarities of the ground control segments for these control activities can be assessed at a fundamental level by comparing Figures 1 and 3.

The study identified some other areas where commonality between pre- and post-launch activities can be increased. The facilities that are used to perform in-orbit testing, including commissioning and performance measurements, could be used in part for the communication payload integration and verifications before launch. Furthermore, it may be possible to use a common software language to express pre-launch test procedures and post-launch operational procedures. The implementation of such a common language could be based on the European Test and Operations Language (ETOL) which is being used for pre- and post-launch activities on all of the communication satellites produced by ESA.

The study also identified around-the-clock staffing of the SCC as a major cost of the operational lifecycle. It may be possible to reduce these costs by automating some operations. The first stages of automation could be implemented during satellite pre-launch thermal vacuum testing. The automated procedures developed could then be used for post-launch activities, particularly for on-station tasks when conditions are stable. This operations methodology could impose an overhead on pre-launch activities. The time required for some pre-launch tests could be increased but it could be balanced against the reduced time required for OCC compatibility testing. In all cases, pre-launch satellite control tasks must be driven by post-launch requirements and expectations.

In conclusion, a more harmonised approach to satellite control could employ established methodologies to reduce duplication over the complete lifecycle of a communications satellite. Furthermore, the standardisation of technologies and methodologies for control centres could be exploited for greater cost effectiveness, with a reduction of risk being a driving factor.

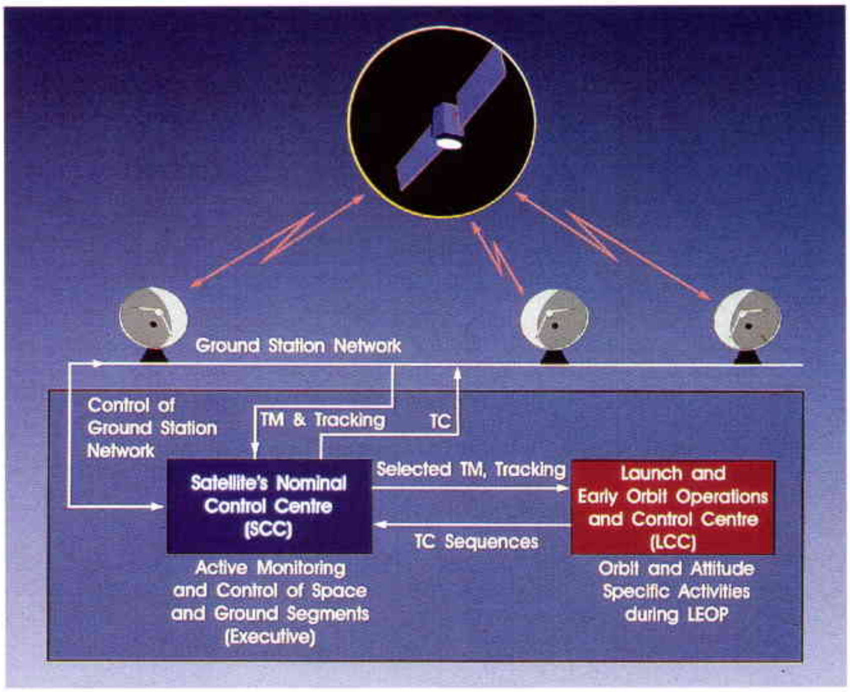


Figure 3. Configuration of post-launch satellite control system, using SCC and LCC

Testing a Scientific Instrument with a Personal Computer

R. Brough*, B. Christensen, J.P.G. Henrion, T.S. Beaufort & T.R. Sanderson**
ESA Space Science Department, ESTEC, Noordwijk, The Netherlands

*ESTEC Mathematics and Software Division

**TERMA Elektronik AS, Lystrup, Denmark

A complex scientific space experiment has recently been tested using just a Personal Computer, off-the-shelf input/output cards and software, and specially written application software.

Introduction

The system described here was developed to test the Analogue Electronics Box of the Three-Dimensional Plasma and Energetic-Particle Experiment being designed and built by ESA Space Science Department at ESTEC. The complexity of this instrument, which is to be flown on NASA's WIND spacecraft, is such that it was impractical to test it without computer-based support equipment.

The equipment described here was required to support all phases of the testing of the Analogue Electronics contained in one box (Fig. 1), namely: the testing both of individual cards and of the complete electronics box, and the collection of data during calibration. Being PC-based, it was both reliable, and portable enough to be shipped around with the instrument.

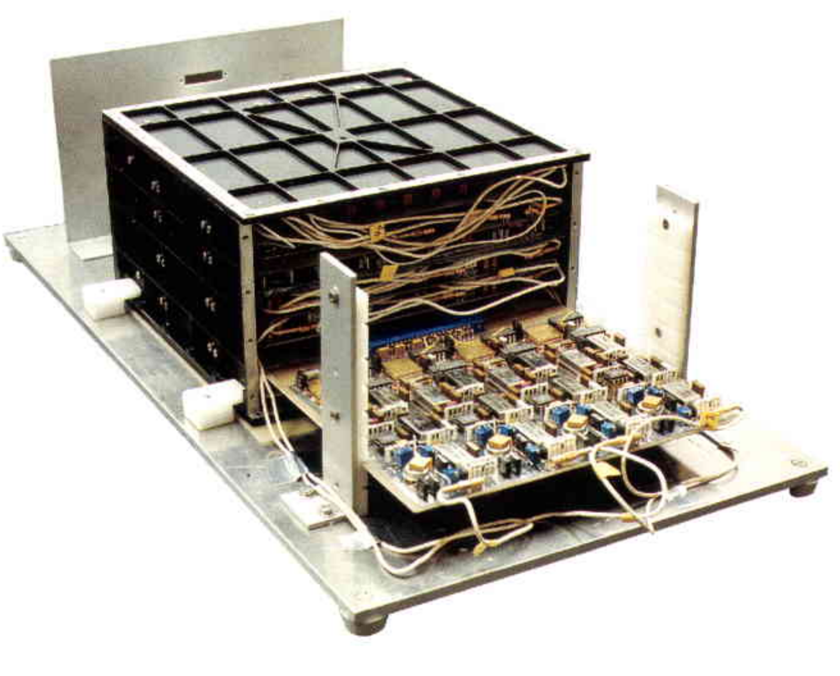


Figure 1. The Analogue Electronics Box of the Three-Dimensional Plasma and Energetic-Particle Experiment

One of the most important aspects is the Graphical User Interface (GUI) that was developed for this system. This interface, which replaced the old-fashioned command-line entry, enables the user to operate the whole system with a mouse.

Hardware

Figure 2 shows how the PC was connected to the instrument being tested. A standard PC was used with selected input/output cards (National Instruments) plugged into the expansion slots. These cards provided the ability to either generate or measure analogue or digital signals, and were connected via cables to either the individual plug-in boards, the Computer-Controlled Test Generators or the complete Electronics Box.

Testing individual boards

During the experiment's design phase, the individual boards that make up the experiment Electronics Box needed testing. Figure 2a shows how a single board was connected to the input/output cards in the PC. Software, described in more detail later, was used to conduct the testing by implementing a simple closed-loop strategy as follows:

a. sending a series of signals to the board
b. reading back the responses of the board
c. comparing the read-back response with the expected response to establish correct functioning of the board.

Testing the complete instrument

Figure 2b shows the configuration used for testing the complete Electronics Box. In this case, an interface card was needed in the PC to provide the link that the Data Processing Unit (DPU) would normally provide in the complete instrument. This interface card was supplied by the Space Sciences Laboratory of the University of Berkeley (California), who were responsible for making the DPU. Test signals to simulate the signals from the Experiment Particle Telescopes were provided by three Precision Programmable Analogue Pulse Generators (Berkeley Nucleonics Corporation Model 9010). Each pulse generator was controlled by an analogue level and a trigger pulse from the PC. Software was used to test the box in a similar manner to the individual boards.

Calibrating the instrument

A third, additional task was to support the calibration of the Experiment. In this case Particle Detector Telescopes were connected to the Electronics Box instead of the computer-controlled test equipment, as shown in Figure 2c. Software was used to collect and display the data.

Software

Figure 3 shows the overall configuration, and the relationship between the hardware and the software. One of the reasons why this PC-based hardware and software approach to testing was adopted was the ease with which the test hardware could be assembled using off-the-shelf interface cards, and the ease with which the off-the-shelf software could be used to drive both the

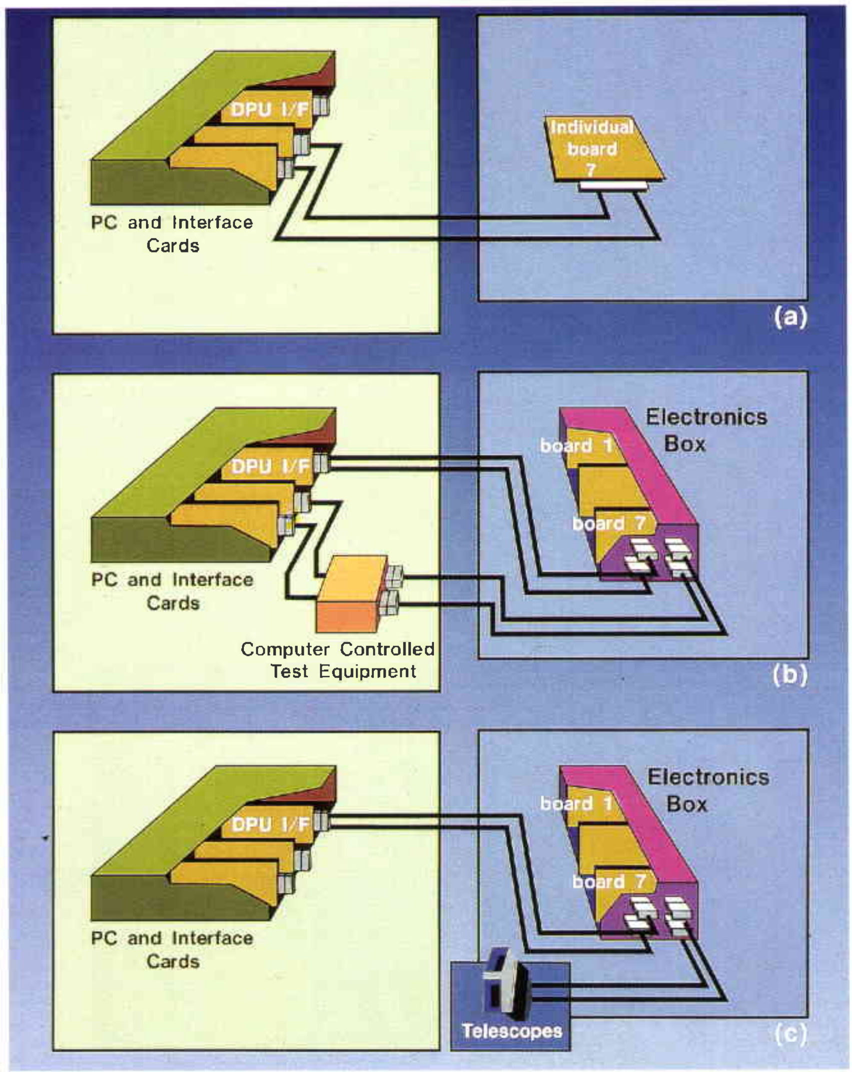


Figure 2. Layout of the instrument support equipment. A standard Personal Computer (PC) is used (Hewlett-Packard Vectra, model QS/20). Input/output cards installed in the PC are connected directly to either the hardware being tested or the computer-controlled test equipment. The hardware layout used for testing individual cards is shown in (a), and that used for testing the complete Analogue Electronics Box in (b). Figure (c) shows the layout used during calibration

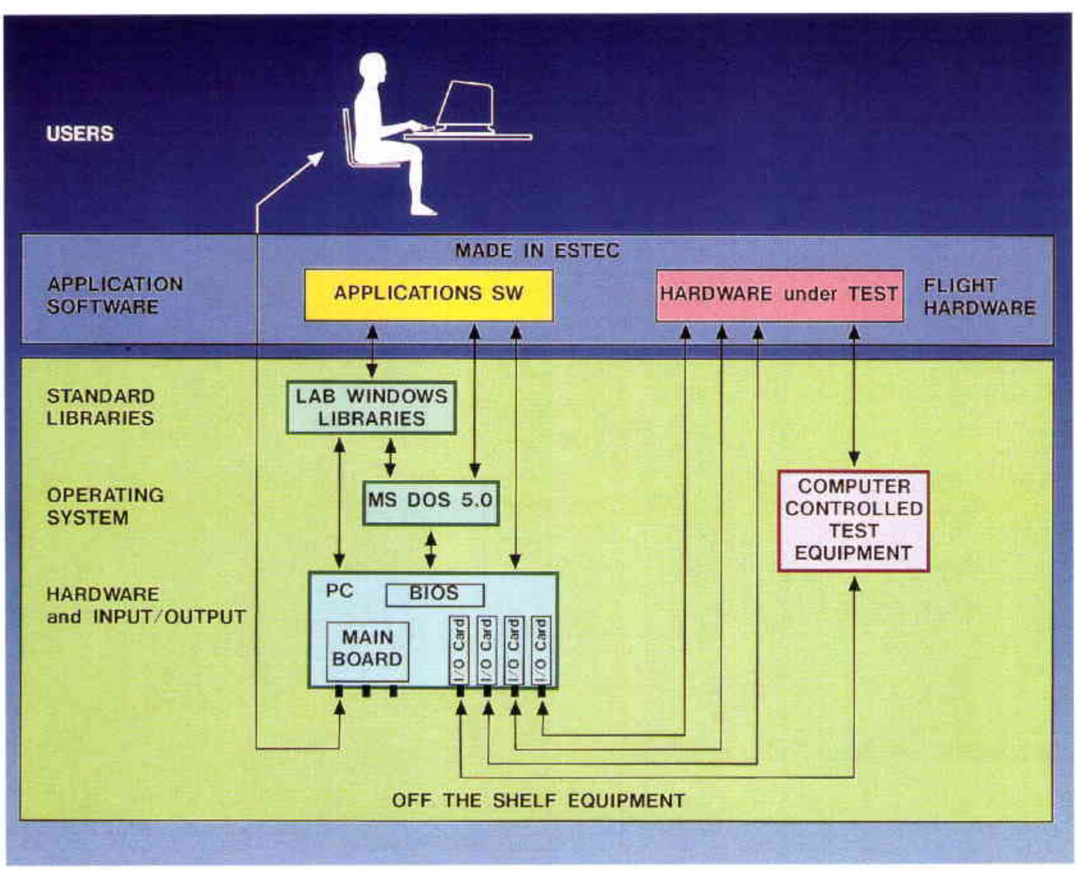


Figure 3. The hardware and software used during flight-hardware testing

The 'LabWindows' Software Package

The 'LabWindows' development package is a PC-based interactive software development package, produced by National Instruments. In conjunction with plug-in interface boards for the PC, it provides a comprehensive general-purpose environment for data acquisition and instrument control, and easy access to a set of software library routines. Using menus such as the example shown in Figure 1, the software engineer can set-up, test and produce the code needed to generate analogue or digital input/output, control an IEEE-standard instrument, or manage the graphical user interface, which is then ready to be pasted into the application software.

The latest versions of 'LabWindows' incorporates extensive Graphical User Interface (GUI) features, including an object-oriented graphical editor, an example of which is shown in Figure 2, for generating the GUI itself. It provides a number of pre-defined graphical objects, which can be used to assemble a user interface. By using these tools, the necessary application software can be developed very rapidly, even by someone with comparatively little experience in either the hardware aspects of the input/output interfaces or GUI design.

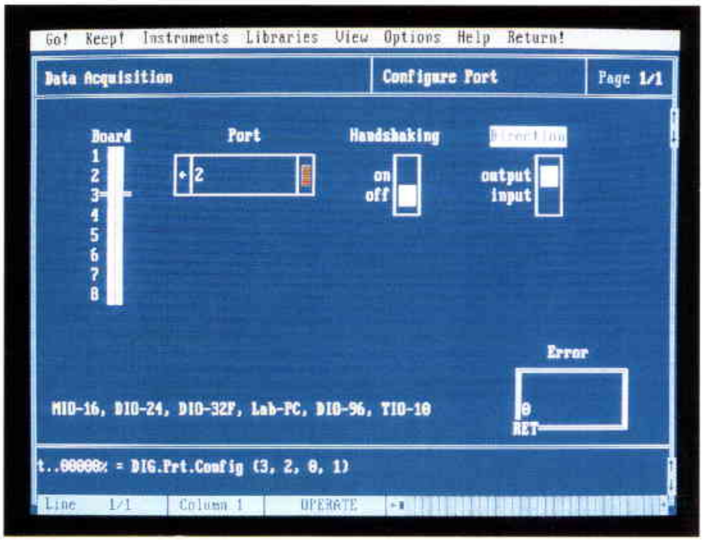


Figure 1. Menu used for generating the software for configuring one of the ports of a four-port interface board in the PC. On the left-hand side it is shown in which slot the I/O card is located; in this example, slot number 3. The next panel shows which of the card's four I/O ports is being configured; in this case port number 2. The next panel shows that handshaking will not be used in the port, whilst the panel on the right-hand side shows that the port will be used as an output port.

The menu also allows the user to test the set-up with the real hardware, and will return an error code in the error window if something is wrong. The software line of code generated automatically appears in the box at the bottom. This line of code can then be added to the application source code being developed.

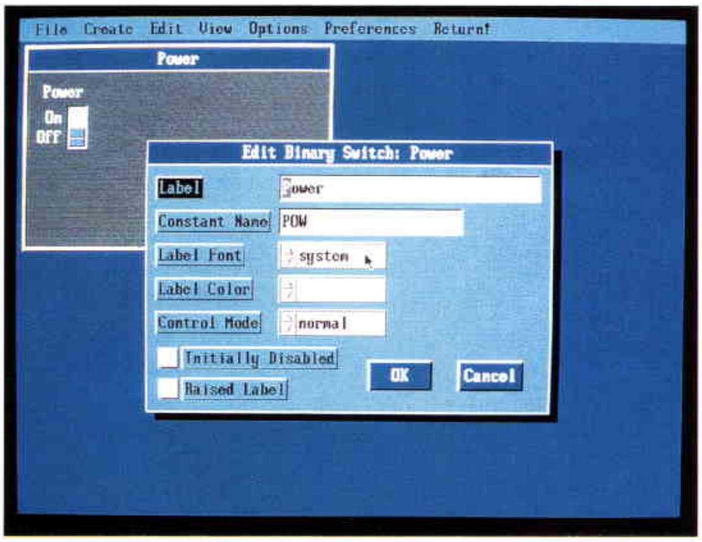


Figure 2. The menu used to develop a Graphical User Interface. The centre panel shows the options available. In this example, the parameters in the panel have been selected, either by using the mouse or by keyboard control, to make a simple power on/off switch. The resulting on/off power panel is shown on the left-hand side. This software for this GUI can then be stored in a separate resource file, to be used by the application program being developed.

Using the Graphical User Interface to Test the Instrument

The four figures here show some of the Graphical User Interfaces developed at ESTEC to test the Analogue Electronics Box. A typical testing sequence would be as follows. After switching on the computer, the software automatically starts and presents the user with a choice of applications. The first screen of one of these applications is shown. The contents of one of the drop-down menus (the 'View' menu) are shown at the top of the display.

The first action is to check the housekeeping of the instrument. Clicking on the mouse button with the pointer located on the 'Power Monitor' panel of the 'View' drop-down menu causes the analogue housekeeping screen to appear. This panel displays the voltages, currents and the temperature being measured by analogue-to-digital converters in the input/output cards. If left on the screen, the measurements are updated every few seconds.

Next, the command screen is displayed by pulling down a similar menu from the 'Commands' drop-down menu with the mouse. Using this menu, all of the commands needed by the instrument can be sent; e.g. switching on and off the high voltage, switching on and off the test generator, changing experiment modes, changing programmable discriminator thresholds, etc. Values can be entered manually, saved to a file, or loaded from a previously prepared file.

Finally, the true operation of the Experiment can be monitored. Clicking on the 'Start' box displays the counting of the channels of the Experiment, with the contents of each channel being shown graphically on the main screen as vertical bars in the 'Spectrum' box, as shown in the figure.

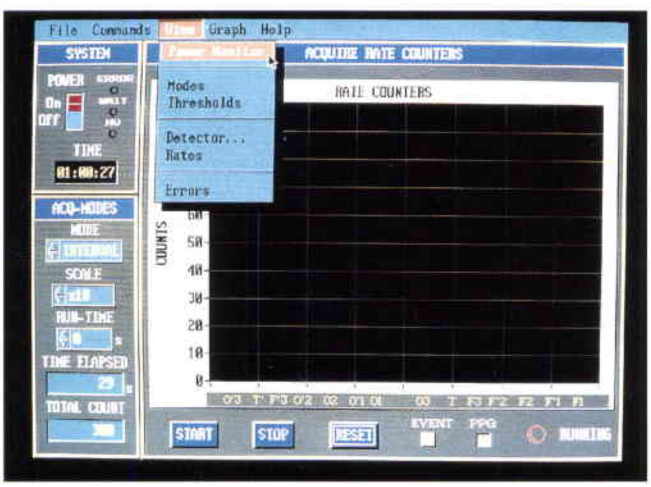


Figure 1. The basic menu

Figure 2. The 'Housekeeping' screen

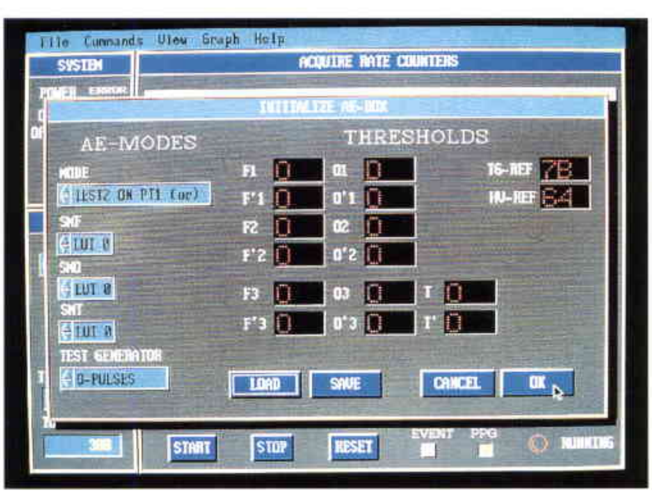


Figure 3. The 'Command' screen

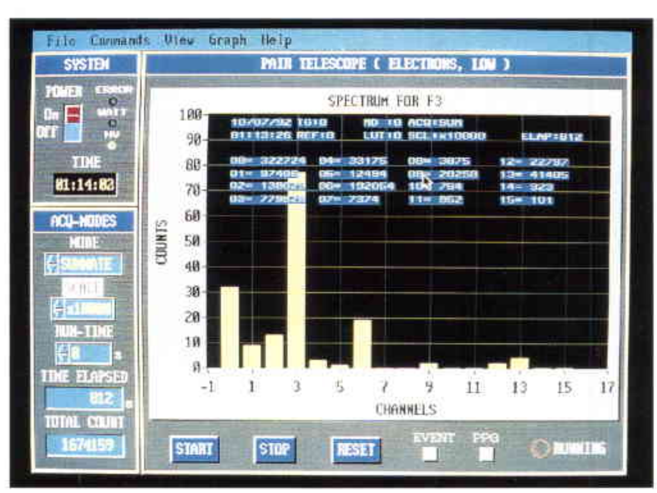


Figure 4. The basic application program

PC and the cards. Assembly of the hardware for the test set-up involved simply plugging-in the input/output cards, and making the connections to the experiment.

By nature, the effort involved in developing software is usually far greater than that involved in assembling the hardware. In our case, the software development effort was considerably less than normal, because we used a software development package to generate both the low-level software required to send signals to, and receive them from, the input/output cards, and the higher-level software needed to generate the graphical user interface. Use of this package, called 'LabWindows' (see accompanying panel), allowed a working prototype to be up and running in only a few days.

Included in the package, and perhaps the most important aspect of LabWindows, is the software to develop a Graphical User Interface (GUI). One of the most usual ways of using a PC is to type in every command manually using the so-called 'command-line interpreter'. This user interface is very tedious to use, since the operator must be able to type reasonably well, and must be able to remember the exact form for each command that has to be entered into the computer.

The GUI is a considerable improvement on the command-line interpreter, enabling a relatively inexperienced computer user to operate the system. All the available commands can be presented on the screen for selection via the mouse, and so the user does not need to memorise them.

A complete suite of application software was developed to support the testing of the Electronics Box. The latter contained analogue amplifiers, analogue-to-digital converters, programmable discriminator thresholds, temperature measurements and so on, all of which needed test software. Modules were needed to test both individual boards and the complete system. These modules were able to:

(i) measure the housekeeping voltages,currents, and temperature
(ii) send commands to switch on and configure the electronics
(iii) trigger a set of programmable pulse generators capable of sending fast-rise-time pulses with accurately known amplitude to the different amplifiers in the Electronics Box
(iv) perform a complete end-to-end functional testing of the Electronics Box to verify its correct operation, and
(v) support the collection of data from the complete assembly of Electronics Box and particle detectors during calibration, which included producing spectra.

A typical application is described in more detail in the accompanying panel on the Graphical User Interface.

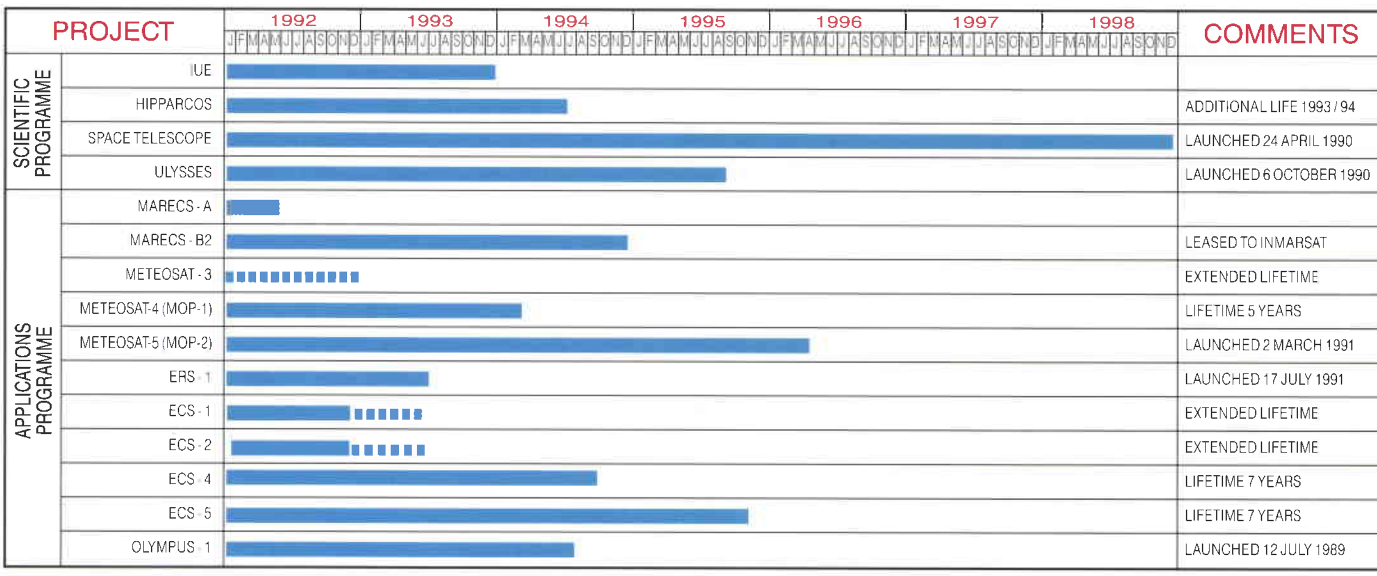
Conclusion

The system outlined above has proved both very successful and extremely easy to set up. A considerable amount of application software has been written, and the resulting operator interface has proved very popular with the engineers responsible for experiment testing. The ease with which new software can be developed has enabled a lively exchange of ideas between the test engineers and the person writing the software, which has further enhanced the usefulness of the system. The latter is also quite compact, allowing it to be easily transported from site to site during the development of the flight instrumentation.

By making use of modern commercial off-the-shelf hardware and software products, it has been possible to develop a complex and professional piece of support equipment very quickly and at low cost. Only the application software had to be written, for which suitable tools were available to speed development. The system has proved so successful that other projects are now using the same concept for their own ground-support and real-time monitoring and control applications.

Programmes under Development and Operations
Programmes en cours de réalisation et d'exploitation

In Orbit / En orbite



Under Development / En cours de réalisation

Télescope spatial

Mission de desserte HST

La NASA a récemment annoncé une date de lancement du 7 Décembre 1993 pour la première mission (STS-61) de desserte du Télescope Spatial Hubble (HST). Au cours de cette mission, l'observatoire HST sera de nouveau abordé par la Navette Spatiale 'Endeavour' et les astronautes remplaceront plusieurs de ses sous-systèmes et instruments scientifiques. Cette mission aura donc deux objectifs: premièrement entretenir le télescope de manière à ce qu'il continue à fonctionner correctement pendant le reste de sa durée de vie, de quinze années, et deuxièmement de rétablir ses moyens scientifiques par l'apport d'optiques de correction permettant de compenser l'aberration sphérique actuelle du miroir principal.

Parmi les éléments qui doivent être remplacés sur ce spationef, figurent plusieurs gyroscopes et cartes de mémoire informatique défaillants, mais redondants, et les panneaux solaires d'origine fournis par l'ESA. La seconde paire de panneaux solaires modifiés est actuellement en cours de fabrication chez British Aerospace à Bristol (UK).

Le problème optique sera résolu en remplaçant deux des cinq instruments scientifiques actuellement à bord du HST. La caméra à grand champ de la NASA sera remplacée par un instrument de même conception, mais dont les optiques ont été modifiées pour compenser l'aberration sphérique du miroir principal. Trois des quatre instruments restant, y compris la caméra pour objets faiblement lumineux (FOC) de l'ESA, bénéficieront également de l'installation du COSTAR, qui sera implanté dans la case à instruments actuellement occupée par le photomètre à grande vitesse. Le seul objectif du COSTAR est le déploiement d'un ensemble de paires de miroirs correctifs de conception appropriée devant chacune des entrées des trois instruments restants. Ces miroirs réorienteront et corrigeront la lumière provenant du télescope avant qu'elle ne pénètre dans les instruments.

L'ESA participe au programme COSTAR en fournissant le modèle structural et thermique FOC (FOC/STM), qui est une copie identique et totalement fonctionnelle du point de vue optique de la caméra FOC, et qui a été monté essentiellement à partir d'éléments de rechange pour le vol. Le modèle FOC/STM permettra de valider l'optique corrective de la caméra FOC du COSTAR avant le vol, en l'installant, avec l'instrument du COSTAR dans une maquette mécanique et optique du télescope HST déformé, qui est construite par le maître d'oeuvre du COSTAR (Ball Aerospace, Boulder, USA). Le modèle FOC/STM remplissant la fonction de la caméra FOC de vol dans la maquette, un essai complet, de bout en bout, de l'optique COSTAR déployée, sera effectué. Le modèle FOC/STM permettra également de tester et de mettre en oeuvre les procédures d'alignement optique sur orbite prévues.

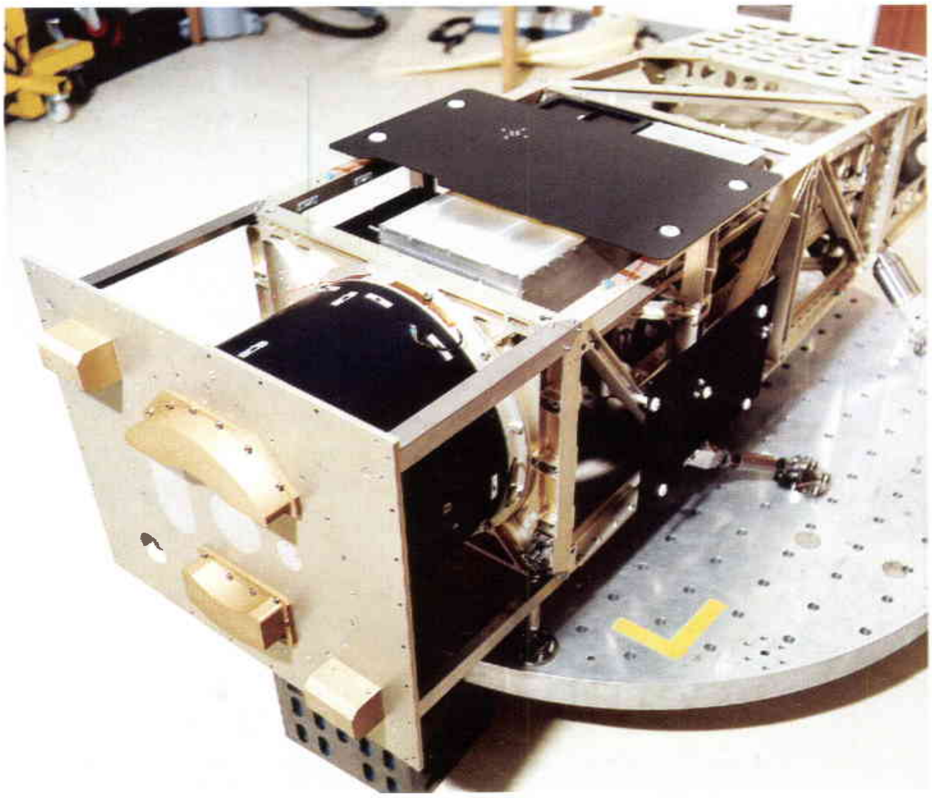
Le modèle FOC/STM a récemment terminé ses essais optiques et de montage chez Matra Marconi Space à Toulouse (F) avant son expédition aux Etats-Unis. Au cours de ses essais, un simulateur optique spécialement conçu, construit par le Laboratoire d'Astronomie Spatiale à Marseille (F), a permis de faire recevoir par le modèle FOC/STM d'une part une image déformée équivalente à celle donnée par le Télescope sur orbite, et d'autre part une image corrigée similaire à celle que la caméra FOC devrait voir, après l'installation de COSTAR. Ces essais optiques ont permis de valider le fait que le modèle FOC/STM est en effet très proche de la représentativité de la caméra FOC de vol sur orbite. Ces essais ont également constitué une première 'répétition pré-générale' de ceux qui devront être conduits ultérieurement aux Etats-Unis avec le COSTAR dans une maquette du HST, et en définitive sur orbite.

Soho

La phase de développement principal de Soho (Phases-C/D) avec Matra Marconi Space comme Maître d'Oeuvre, progresse de manière satisfaisante vers le montage des modèles structuraux et technologiques de spationefs.

Les activités industrielles au cours des mois d'été ont porté essentiellement sur la fabrication des matériels et logiciele concernés, et sur la préparation des activités de montage, intégration et essai (AIT).

Structural model of the Soho Coronal Diagnostic Spectrometer experiment during vibration testing (Photo courtesy of Rutherford Appleton Laboratories, UK)



Space Telescope

The HST servicing mission

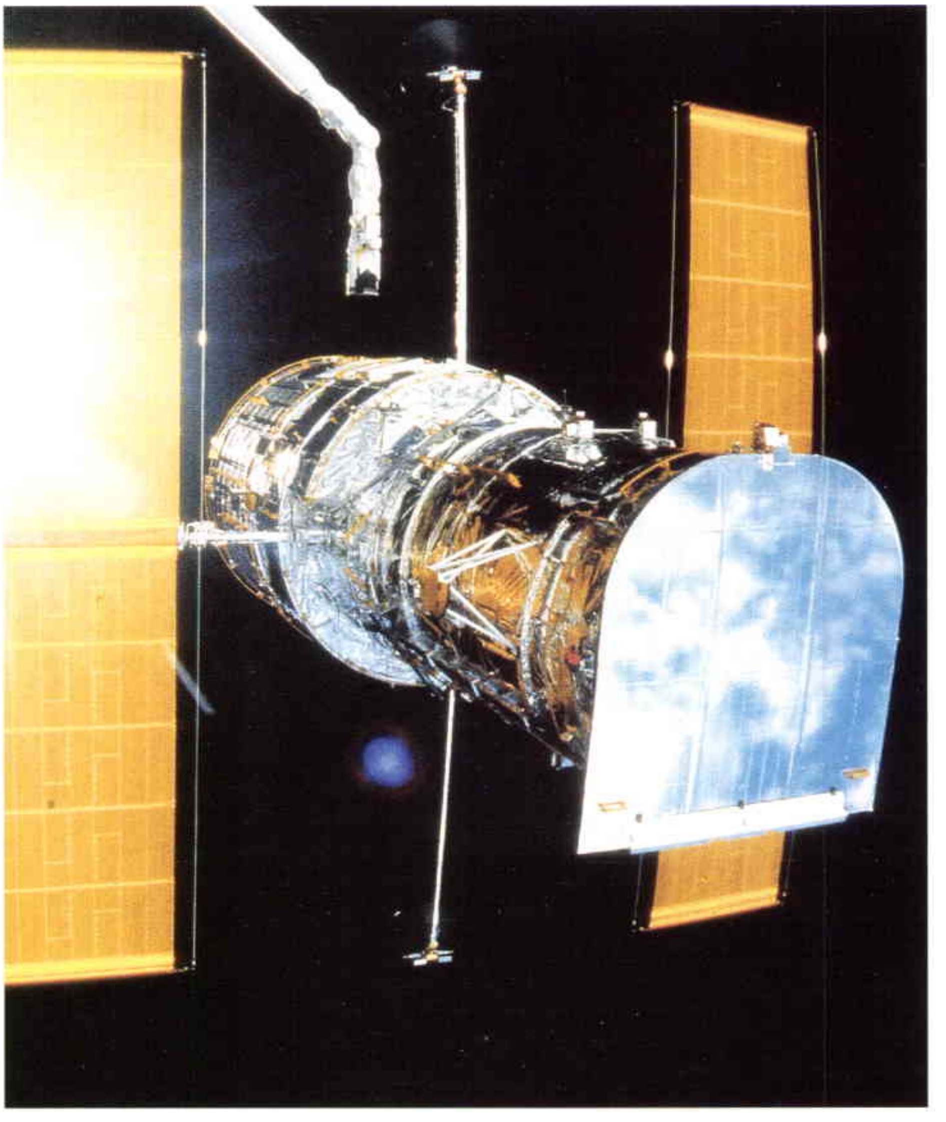
NASA has recently announced a launch date of 7 December 1993 for the first Hubble Space Telescope servicing mission (STS-61). During this mission the HST observatory will be recaptured by the Space Shuttle 'Endeavour' and astronauts will exchange several of the spacecraft subsystems and scientific instruments. The purpose of this is twofold: to carry out the spacecraft maintenance required to keep the HST facility operational for its projected 15 year lifetime, and to recover the scientific capabilities of the observatory by introducing corrective optics designed to compensate for the spherical aberration currently affecting the HST primary mirror.

Included in the spacecraft items slated for exchange are several failed, but redundant, gyroscope units and flight-computer memory boards, and the original ESA-supplied solar arrays. The second, modified pair of solar arrays are currently being manufactured by British Aerospace in Bristol (UK).

The optical problem will be overcome by exchanging two of the five scientific instruments presently onboard HST. NASA's Wide-Field Planetary Camera will be replaced by an instrument of the same design whose optics have been modified to compensate for the primary mirror's spherical aberration. Three of the remaining four instruments – including ESA's Faint-Object Camera (FOC) – will in turn benefit from the installation of COSTAR (Corrective Optics Space Telescope Axial Replacement), which will take up the instrument bay presently occupied by the High-Speed Photometer. The sole purpose of COSTAR is to deploy a set of suitably designed pairs of corrective mirrors in front of each of the entrances to the three remaining instruments. These mirrors will redirect and correct the light from the telescope before it enters the instruments.

ESA is participating in the COSTAR programme through provision of the so-called 'FOC Structural and Thermal Model' (FOC/STM), which is a highly representative and optically fully functional copy of the FOC, which has been assembled largely from flight-spare components. The FOC/STM will be used to validate the COSTAR FOC corrective optics prior to flight by installing it, together with the flight COSTAR instrument, into a mechanical and optical mock-up of the aberrated HST telescope that is being built by the COSTAR prime contractor (Ball Aerospace, Boulder, USA). With the FOC/STM playing the role of the flight FOC in the mock-up, a complete end-to-end test of the deployed COSTAR optics will be conducted. The FOC/STM will aso enable the planned in-orbit optical-alignment procedures to be tested and practised.

The FOC/STM has recently completed assembly and optical testing at Matra-Marconi Space in Toulouse (F) prior to shipment to the USA. During these tests, a specially designed optical simulator, built by Laboratoire d'Astronomie Spatiale in Marseille (F), was used to feed the FOC/STM both an aberrated image equivalent to that provided by the Telescope in orbit, and a corrected image similar to that which the FOC should see once COSTAR has been installed. These optical tests served to validate the fact that the FOC/STM is indeed closely representative of the flight FOC in orbit. The tests also constituted a first 'dress rehearsal' for the testing to be conducted later in the USA with the flight COSTAR in the HST mockup – and ultimately in orbit.



Deployment of the Hubble Space Telescope (photo courtesy of NASA)

Soho

The Soho main development phase (Phase-C/D) with Matra Marconi Space as Prime Contractor, is proceeding towards assembly of the spacecraft structural and engineering models.

Certaines activités de fabrication de matériel de vol ont déjà débuté, la structure du module de charge utile en étant l'exemple le plus remarquable.

Des revues de conception de sous-systèmes ont été effectuées et un ensemble de données de revue de conception de matériel (HDR) au niveau système, a été livré par le Maître d'Oeuvre à la mi-Juillet. L'avancement de la revue elle-même a été conforme aux prévisions au cours du mois d'Août, et celle-ci sera conduite à bonne fin par une Commission, le 23 Septembre. Le but de cette revue HDR est d'autoriser le lancement d'activités portant sur le modèle technologique.

Les procédures de contrôle de propreté sont en cours de finalisation en vue de leur application aux activités AIT du modèle de vol.

Coopération ESA/NASA

La coopération ESA/NASA se poursuit de manière satisfaisante. Les modèles technologiques de l'amplificateur grande puissance (Cubic, USA), de l'enregistreur sur bande (Odetics, USA) et du suiveur solaire de précision (Adcole, USA), ont été livrés. La fabrication du modèle de vol se poursuit. Les programmes des procédures de qualification et de recette ont été évoqués de façon détaillée et sont actuellement l'objet des dernières retouches.

On a également avancé sur l'interface du lanceur, grâce à des réunions portant sur l'interface spécialisée, organisées avec le Centre de recherche Lewis de la NASA et General Dynamics, fournisseur du véhicule Atlas-IIAS.

Les travaux portant sur l'exploitation en vol et sur la mise en oeuvre du secteur sol sont actuellement très avancés. Une revue des exigences de système du secteur sol s'est tenue au Centre des Vols Spatiaux Goddard à la fin du mois d'Août, des experts de la NASA en matière d'exploitation et de secteurs sol ayant contribué à la revue HDR.

Charge utile

Les expériences Soho sont très en avance sur les programmes et plusieurs modèles de vol des instruments sont déjà en phase initiale d'achat et de fabrication.

Un groupe de travail scientifique s'est réuni à Killarney (Irlande) au mois de Juin, pendant lequel la livraison des modèles structuraux et électriques des expériences a été confirmée, conformément aux prévisions, pour le dernier trimestre de l'année.

Certains problèmes particuliers de financement ont été résolus au mois de Juin.

Cluster

Une anomalie a été observée au cours des essais du modèle structural de spationef, effectués à l'IABG de Munich (D) au début du mois de Juillet. Des enquêtes ultérieures ont révélé qu'un mode dissymétrique de la plate-forme principale d'équipement était passé inaperçu au cours de l'analyse de l'empilement pendant les essais. La cause de ce problème ayant été identifiée de manière satisfaisante, le modèle structural sera remis en état et le reste du programme de qualification sera poursuivi. Les travaux afférents devraient être repris en janvier 1993, à l'IABG.

Le programme de modèle technologique a été retardé au cours des mois d'été, du fait des modifications de conception apportées aux sous-systèmes en vue de corriger les anomalies de compatibilité électromagnétique (EMC). Il est prévu de recommencer l'intégration finale au cours du mois de Septembre, l'intégration de charge utile devant débuter vers la fin Octobre.

Certaines unités de charge utile de modèle technologique ont déjà été livrées à Dornier (D), le solde devant parvenir à destination au cours des mois de Septembre et d'Octobre.

Le calendrier concernant les modèles de vol est maintenu, malgré les retards dus aux modèles technologiques, en prenant les dispositions requises en vue d'accroître les activités parallèles simultanées pouvant intéresser jusqu'à trois spationefs.

L'avancement du système de données scientifiques Cluster (CSDS) est conforme aux prévisions, la documentation des interfaces des groupes participants étant approuvée et diffusée. Actuellement, l'Agence étudie la possibilité d'inclure l'Académie des Sciences de Chimie, dans le système CSDS, à la suite de sa réponse à l'Annonce d'Opportunité (AO). Une décision devrait été prise au début de 1993.

La fabrication et l'essai du modèle technologique de l'unité de mémoire de Mars 94 sont pratiquement terminés et la revue critique de conception (CDR) est prévue pour la mi-Septembre.

ISO

Instruments scientifiques

Les groupes de Chercheurs Principaux progressent de manière satisfaisante vers la conduite à bonne fin de leur matériel d'instruments scientifiques pour modèle de vol. ISOPHOT vient de terminer les essais de recette de ces unités destinées aux modèles de vol. Les unités de commande électronique des instruments scientifiques seront intégrées à la plate-forme supérieure du module de service ISO vers la fin de l'année. Les unités du plan focal seront stockées jusqu'au moment de leur installation sur le télescope du modèle de vol, au début de 1993.

Les unités de rechange de vol des quatre instruments scientifiques ISO devraient être mises à disposition au cours du printemps de l'année prochaine.

Satellite

Les travaux portant sur les matériels de vol du satellite ont été essentiellement dominés par les deux problèmes techniques prioritaires du projet. Ceux concernant le télescope et les vannes à hélium liquide du module de charge utile.

Le télescope est actuellement reconstruit à partir du miroir principal de rechange, du fait que le miroir précédent présentait des imperfections et une contamination excessives. Ces travaux d'intégration du télescope se poursuivent de manière satisfaisante, en prenant toutes les précautions possibles pour réduire au minimum tous risques de contamination.

Industrial activities during the summer months have been concentrated on the production of relevant hardware and software, and on preparation for the Assembly, Integration and Test (AIT) activities.

Some flight-hardware manufacturing activity has already started, the payload-module structure being the most notable example.

Subsystem design reviews have been taking place and the system level Hardware Design Review (HDR) data package has been delivered by the Prime Contractor in mid-July. The review itself has progressed according to plan during August, and will be concluded by a Board meeting on 23 September. The HDR is intended to authorise the commencement of the engineering-model activities.

Cleanliness control procedures are being finalised ready for their implementation in the flight-model AIT activities.

ESA/NASA cooperation

ESA/NASA cooperation is proceeding satisfactorily. The first high-power-amplifier (Cubics, USA), tape-recorder (Odetics, USA) and fine-pointing Sun-sensor (Adcole, USA) engineering models have been delivered. Flight-model manufacture is in progress. Details of qualification and acceptance programmes and procedures have been discussed and are now being finalised.

Progress has also been made on the launcher interface through dedicated interface meetings with NASA Lewis Research Center and General Dynamics, supplier of the Atlas-IIAS vehicle.

Work on the flight operations and on the implementation of the ground segment is now at a very advanced stage. A system-requirements review of the ground segment was held in Goddard Space-Flight Center in late August, and NASA operations and ground segments experts have contributed to the HDR.

Payload

The Soho experiments are well ahead in their planned development and several flight models of the instruments are already in the initial phases of procurement and manufacture.

A Science Working Team meeting took place in June in Killarney (Ireland), at which delivery of structural and electrical models of the experiments have been confirmed to take place as planned during the last quarter of this year.

Some specific funding problems were successfully resolved in June.

Cluster

An anomaly occurred during testing of the structural-model spacecraft at IABG in Munich (D) in early July. Subsequent investigations have shown that an asymmetric mode of the main equipment platform had been overlooked during the analysis of the stack configuration during test. Having satisfactorily identified the cause of the problem, the structural model will be refurbished and the remainder of the qualification programme undertaken. The latter is expected to recommence at IABG in January 1993.

The engineering-model programme has been delayed over the summer months whilst design modifications were introduced into subsystems to correct EMC anomalies. Final integration is scheduled to recommence in September, with payload integration due to start towards the end of October.

Some engineering-model payload units have already been delivered to Dornier (D), with the remainder due to arrive in during September/October.

The schedule for the flight models is still being maintained, despite the engineering-model delays, by making provisions for more parallel activities on up to three spacecraft at a time.

Progress on the Cluster Science Data System is on schedule, with participating-group interface documentation approved and issued. Currently, the Agency is examining the possibility of including the Chinese Academy of Sciences in the CSDS System, following their response to the Announcement of Opportunity (AO). A decision is expected in early 1993.

Manufacture and testing of the engineering model of the Mars'94 memory unit is almost complete and the Critical Design Review (CDR) is scheduled for mid-September.

ISO

Scientific instruments

The Principal Investigator groups are making good progress with the completion of their flight-model scientific instrument hardware. ISOPHOT has completed acceptance testing of its flight-model units. The electronics control units of the scientific instruments will be integrated onto the ISO service module's upper platform by the end of this year. The focal-plane units will be stored until they are needed for installation on the flight-model telescope early in 1993.

The flight-spare units of the four ISO scientific instruments are expected to be available in the spring of next year.

Satellite

Work on the satellite flight hardware has been largely dominated by the two top-priority technical problems of the project, those of the telescope and of the liquid-helium valves in the payload module.

The telescope is now being rebuilt using the spare primary mirror, because the previous mirror was found to be suffering from excessive blemishes and contamination. This telescope integration work is proceeding satisfactorily, taking all possible precautions to minimise any risk of contamination.

The problem of obtaining a satisfactory set of liquid-helium valves for the payload-module cryostat is being pursued along several parallel paths. The original valve is being improved in terms of its detailed design, and a back-up design with improved mechanical guidance is being produced in parallel. In addition, prototype valves of completely different design are being procured by new independent suppliers. Pre-qualification demonstration testing has just started on several valves of different types. These tests will be followed by qualification tests, the results of which will determine which type of valve is ultimately selected for flight.

All other flight-model work is proceeding satisfactorily. The valve problems and late telescope delivery are dictating the overall project schedule. All project efforts are geared towards obtaining a suitable qualified valve by the end of this year.

Le problème de réalisation d'un ensemble satisfaisant de vannes à l'hélium liquide pour le cryostat du module de charge utile est actuellement étudié selon plusieurs cheminements parallèles. La vanne d'origine est améliorée du point de vue de sa conception détaillée, et une conception de secours, à guidage mécanique perfectionné est élaborée parallèlement. De surcroît, des vannes prototypes de conception entièrement différentes sont commandées à de nouveaux fournisseurs indépendants. Les essais de démonstration de pré-qualification viennent de commencer sur plusieurs vannes de différents types. Ils seront suivis d'essais de qualification, dont les résultats permettront de choisir en définitive le type de vanne le mieux adapté au vol.

Tous les autres travaux portant sur les modèles de vol se poursuivent de manière satisfaisante. Les problèmes afférents aux vannes et au retard de livraison du télescope imposent le calendrier d'ensemble du projet. Toutes les activités concernées ont pour but d'obtenir une vanne qualifiée de façon satisfaisante pour la fin de l'année.

Secteur sol
L'état d'avancement du secteur sol est satisfaisant. Le développement des logiciels d'exploitation scientifique est complexe et exige une attention particulière. L'ESA, le Japon et la NASA ont étudié ensemble les possibilités d'une coopération qui permettrait d'aboutir à une augmentation des observations scientifiques d'ISO, grâce à une seconde station terrestre.

Huygens

Les travaux se sont activement poursuivis au cours de l'été alors que la phase de définition détaillée était en voie d'achèvement. Des revues de conception préliminaire ont eu lieu pour l'ensemble des sous-systèmes et expériences, ce qui a permis de préparer la revue de conception système (SDR) marquant l'étape finale de la phase-B. Pour atteindre cette étape, il a fallu constituer presque toute l'équipe industrielle sous sa forme plus ou moins définitive, la couverture contractuelle de la majorité des entreprises étant toutefois limitée (en termes financiers et en durée) aux activités nécessaires pour assurer le bon déroulement de la SDR. La date-butoir pour l'achèvement des activités de conception et le démarrage de la préparation des lots de données SDR était fixée au 28 août, les données devant être communiquées à l'ESA à la mi-septembre.

Les interfaces entre le lanceur et Cassini, l'orbiteur de Saturne, sont en voie de consolidation, de même que les questions connexes; des engagements ont été pris en vue d'un lancement en 1997. Cassini a fait l'objet de quelques modifications techniques qui ont eu une incidence sur la conception de la sonde Huygens et qui, malgré les changements de configuration en résultant, auront pour effet d'améliorer les manoeuvres lors de la descente de la sonde vers Titan.

XMM

Les travaux conduits sur le modèle de développement du miroir (MDM) afin de démontrer le fonctionnement de l'ensemble de miroirs dans le rayonnement X se déroulent comme prévu. On a construit trois coquilles de miroir en nickel et deux coquilles en fibres de carbone. Elles serviront à établir les caractéristiques de fonctionnement dans le rayonnement X avant de passer à la fabrication de miroirs supplémentaires de diamètres différents devant être utilisés dans le MDM. Au total, quatre miroirs en coquille de 30 à 60 cm de diamètre seront assemblés. Le MDM devrait être disponible début 1993 pour des essais dans le rayonnement X.

Le XMM fait actuellement l'objet de deux études de phase A, l'une en association avec le projet Prisma et l'autre avec le projet Integral. Ces deux projets pourraient être choisis comme prochaine mission scientifique (M2) de l'ESA. Dans les deux cas, on étudie la possibilité d'utiliser pour la mission M2 une plate-forme d'observation identique à celle du satellite XMM.

ERS

ERS-1
Après plus d'un an d'exploitation en orbite, le fonctionnement technique du satellite reste excellent.

Le cycle adopté depuis le début avril 1992 qui fait repasser le satellite tous les 35 jours au-dessus des mêmes sites permet la couverture complète des zones situées à portée des stations de l'ESA, nationales et étrangères, capables de recevoir les données du radar à synthèse d'ouverture (SAR) d'ERS-1. L'accent a donc été mis sur l'acquisition d'une couverture SAR complète de toutes ces zones tout en maintenant la mission Océans-glaces à l'échelle du globe.

L'ATSR a perdu le canal à 3,7 µm. Bien qu'il en résulte une légère dégradation des corrections du produit 'température de surface de la mer' (SST) de nuit, le produit ATSR reste dans les limites des caractéristiques spécifiées.

Le service de livraison rapide continue d'être assuré aux utilisateurs sur la base d'un taux de disponibilité très élevé. Des mises à jour ont été faites pour renforcer les algorithmes (notamment pour les produits 'vents') et consolider le service de distribution des données SAR du satellite. Le traitement en différé a bien avancé et l'arriéré existant s'est notablement réduit.

Le premier symposium ERS-1 qui doit se tenir à Cannes du 4 au 6 novembre 1992 offrira aux nombreux scientifiques qui participent à l'évaluation des données d'ERS-1 l'occasion de présenter et comparer les résultats obtenus.

Le produit donnant les formes d'ondes originelles résultant de deux cycles de trois jours en août 1991, l'un en mode 'glaces' et l'autre en mode 'océans', a été élaboré dans la PAF du Royaume-Uni et des copies en ont été distribuées aux chercheurs principaux (PI).

Le manuel des utilisateurs d'ERS-1 (ESA/SP-1148) et le document donnant les spécifications des produits ERS-1 de l'ESA (ESA/SP-1149)* ont été distribués*

** Des exemplaires sont disponibles auprès de la division des publications de l'ESA.*

Ground segment
The ground segment is progressing satisfactorily. The development of science operations software is a complex task that is demanding extra attention. Further discussions have taken place between ESA, Japan and NASA on possible cooperation which would lead to an increase in ISO's science observations via the provision of a second ground station.

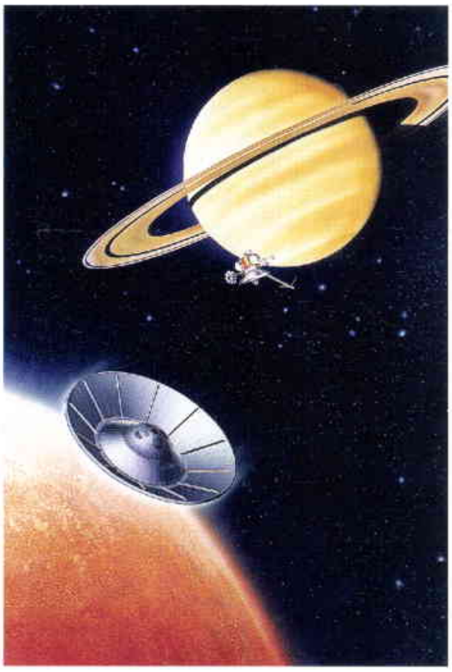
Huygens

Activities throughout the summer have been intense as the project progresses towards completion of the detailed design phase. Preliminary Design Reviews (PDRs) have been held for all of the subsystems and experiments, permitting preparations for the final milestone of Phase-B, namely the System Design Review (SDR), to proceed. To achieve this status, it has been necessary to build up virtually the full industrial team in more or less final form, but with contractual coverage for the majority of the companies limited (both financially and in duration) to those activities needed to ensure satisfactory SDR status. The cut-off date for termination of design activities and the starting of the preparation of SDR data packages was 28 August, with data submission to ESA scheduled for mid-September.

Launcher and Cassini Saturn Orbiter spacecraft interfaces and related issues are becoming much firmer, with commitments to a 1997 launch opportunity. Some technical changes to the Cassini spacecraft have been identified which have had an effect upon the Huygens Probe design and, although causing the configuration to be amended, will ultimately result in improvements in operations during the Titan descent phase.

XMM

Work on the Mirror Development Model (MDM) to demonstrate the X-ray performance of the mirror assembly is proceeding as planned. Three replicated nickel mirror shells and two replicated carbon-fibre mirrors have been produced. These will be used to establish the X-ray performance before proceeding with the build-up of additional mirror shells of different diameters to be used in the MDM. A total of four mirror shells will be fitted, with diameters ranging from 30 to 60 cm. The MDM is planned to be available in early 1993 for X-ray testing.



The Cassini Saturn Orbiter and Huygens Probe

Two Phase-A studies of XMM are being conducted, one in conjunction with Prisma and the other in conjunction with Integral. These two missions are candidates for selection as the next ESA scientific mission (M2). Both studies are examining the possibility of using a duplicate of the XMM spacecraft bus as a platform for the M2 mission.

ERS

ERS-1
After more than one year of in-orbit operations, the technical performance of the satellite remains excellent.

The 35-day orbit repeat cycle initiated in early April 1992 allows full coverage to be obtained of the zones within range of the ESA, National and Foreign Stations capable of acquiring ERS-1 Synthetic Aperture Radar (SAR) data. Emphasis has therefore been put on acquiring a complete SAR coverage of all of these zones whilst maintaining the Global Ocean-Ice mission.

The ATSR has lost the 3.7 micron channel. Although this slightly degrades the corrections of the Sea-Surface Temperature (SST) product by night, the ATSR product remains within its specified performance.

The Fast-Delivery Service has continued to be provided to the users with very high availability. Updates have been performed to enhance the algorithms (wind product in particular) and to improve the robustness of the satellite SAR dissemination service. Offline processing has made significant progress in reducing the existing backlog.

The first ERS-1 Symposium, to be held in Cannes on 4–6 November 1992, will provide an opportunity to the wide scientific community involved in the evaluation of ERS-1 data to present and compare their results.

The Waveform Foundation Product related to two three-day cycles in August 1991, namely one in 'ice mode' and one in 'ocean mode', has been generated at the UK-PAF and copies distributed to the Principal Investigators (PIs).

The ERS-1 User Handbook (ESA SP-1148)* and the ESA ERS-1 Product Specification document (ESA SP-1149)* have been distributed to the user community. The ERS-1 System document (SP-1146)* and the ERS-1 CD guide (SP-1155)* has been completed for distribution and promotional purposes. It contains information on the ERS-1 system, data applications and technical features.

A PC program has been developed for visualising and consulting the catalogue of SAR data acquired worldwide and for preparing user orders. It is available on request.

ERS-2
Satisfactory progress continues to be made on ERS-2. All payload equipment items are now complete and instrument

* Copies available from ESA Publications Division.

aux utilisateurs. Le document du système d'ERS-1 (ESA/SP-1146) et le guide sur CD d'ERS-1 (ESA/SP-1155)* ont été mis au point aux fins de diffusion et de promotion. Il contient des renseignements sur le système ERS-1, les applications de ses données et ses caractéristiques techniques.*

Un programme PC, disponible sur demande, a été mis au point pour la visualisation et la consultation du catalogue des données SAR acquises dans le monde entier et pour l'établissement des commandes des utilisateurs.

ERS-2
L'avancement des activités relatives à ERS-2 se poursuit de façon satisfaisante. Les équipements composant la charge utile sont au complet et l'intégration et les essais des instruments sont en cours. L'intégration de la charge utile démarrera sous peu. La fabrication des éléments de la plate-forme est bien avancée; l'intégration du module de propulsion est en route et celle du module de servitude doit commencer vers la fin de l'année.

Les travaux relatifs à l'instrument de surveillance de l'ozone, le GOME, progressent: le module électronique prototype est en voie d'achèvement et la plupart des éléments optiques sont soit déjà livrés soit aux derniers stades de leur réalisation. Quelques retards sont à prévoir par rapport au calendrier mais on s'efforce d'en pallier les incidences dans toute la mesure possible.

Météosat

Les satellites Météosat-4 et 5 sont l'un en service opérationnel et l'autre en position de réserve en orbite à la longitude 0° tandis que le satellite Météosat-3, à poste par 50° de longitude ouest, fournit des images de la zone ouest de l'Atlantique.

L'intégration du dernier satellite de la série opérationnelle, MOP-3, se déroule actuellement dans la salle propre de l'Aérospatiale, à Cannes (F). Son lancement par une fusée Ariane est prévu au dernier trimestre de 1993. Dans le cadre de la suite du programme, le programme de transition Météosat, un autre satellite du type Météosat est construit pour Eumetsat.

L'approvisionnement des éléments de ce véhicule spatial et d'un deuxième satellite en option est en cours. La construction des sous-systèmes de satellite a commencé par celle de la structure. Le lancement est prévu en 1995.

Earthnet

Le radar à synthèse d'ouverture (SAR) et le détecteur optique (OPS) du satellite japonais JERS-1 présentent un fonctionnement nominal. La station Esrange-Kiruna a capté les données des passages de l'OPS et Tromsø celles de quelques passages du SAR. Les chaînes de traitement des données du SAR de JERS-1 sont en cours de réalisation et leur installation finale à Fucino, au DLR, à l'ESRIN et à Tromsø est prévue pour novembre.

L'enregistreur sur bande optique prévu pour l'archivage des données historiques de Landsat a été mis en place a Frascati et son intégration dans le système de transcription est en cours.

La mise au point de la chaîne de traitement de l'instrument de cartographie thématique amélioré (ETM) de Landsat-6 se poursuit conformément au calendrier, et des essais sont en cours sur les données TM de Landsat-4/5.

Les stations de Fucino et de Kiruna assurent l'acquisition des données, leur archivage et l'élaboration des produits destinés aux utilisateurs dans le cadre des opérations courantes pour les missions Landsat et MOS (satellite d'observation des mers), tandis que Maspalomas a repris les opérations Spot, en sus de ses activités MOS et Tiros, à la suite d'un accord ad-hoc avec Spotimage.

Les stations du réseau coordonné Earthnet assurent l'acquisition et l'archivage réguliers des données HRPT (transmission d'images à haute résolution) de NOAA-11 (après-midi) et NOAA-12 (matin), tandis que l'intégration de la station de Scanzano dans le réseau progresse.

Dans le cadre du projet commun NASA/NOAA/ESA qui vise la production d'un ensemble de données AVHRR (radiomètre de pointe à très haute résolution) à l'échelle du globe sur les terres, offrant une résolution de 1 km, il est actuellement procédé à la collecte opérationnelle de données dans différents centres du monde entier.

En ce qui concerne le projet ANASE (Association des nations de l'Asie du sud-est, en anglais ASEAN), la station de Bangkok est actuellement mise à niveau pour l'acquisition et le prétraitement des données du SAR d'ERS-1.

Le contrat GENIUS (Global Environment space data Network and Information User System) avec la Swedish Space Corporation et ses partenaires poursuit son cours.

Les activités Earthnet relatives au secteur sol de la charge utile d'ERS-1 sont traitées sous la rubrique ERS-1.

EOPP

Aristoteles
La proposition de programme Aristoteles que l'Exécutif a publiée pour examen avec les participants potentiels a été mise à jour en fonction d'une offre faite par la NASA d'accroître sa participation.

Les activités industrielles se poursuivent avec la négociation de la prolongation de la phase A et la mise en route de nouvelles activités de prédéveloppement d'instrument (Gradio) et d'autres activités de soutien.

Météosat de deuxième génération
La proposition de programme Météosat de deuxième génération (MSG) portant sur la réalisation du premier satellite a été publiée en préparation de la première réunion des participants potentiels, tenue en octobre 1992.

Les études industrielles de phase A du satellite ont franchi l'étape de la revue à mi-parcours. De nouveaux travaux sont lancés sur l'imageur et l'antenne de distribution des données.

Missions sur orbite terrestre basse
Les travaux se poursuivent sur la

integration and testing is underway. Payload integration will start shortly. Manufacture of the platform elements is well advanced, with integration of the propulsion module now underway and service-module integration due to start towards the end of the year.

Progress has been made on the GOME Ozone Monitoring Instrument, with the prototype electronics module nearing completion, and most of the optical elements either already delivered or in the final stages of development. Some schedule delays are anticipated, but work-arounds are being used to minimise their impacts.

Meteosat

Meteosat-4 and 5 provide the operational service and in-orbit standby at the 0° longitude, whilst Meteosat-3 provides imaging of the western Atlantic from its 50°W position.

The integration of the last spacecraft in the operational series, MOP-3, is now underway in the clean room at Aerospatiale, in Cannes (F). It is scheduled for an Ariane launch in the last quarter of 1993.

In the follow-on programme, the Meteosat Transition Programme, one more spacecraft of the Meteosat type is being built for Eumetsat. Components for this spacecraft and for a second optional one are presently being procured. The building of the spacecraft subsystems has started with the structure. Launch is foreseen in 1995.

Earthnet

Both the Synthetic Aperture Radar (SAR) and Optical Sensor (OPS) instruments on Japan's JERS-1 are working nominally. OPS passes have been acquired at the Esrange–Kiruna station and a few SAR passes were acquired at Tromsø. JERS-1/SAR processing chains are under development, with final installation at Fucino, DLR, ESRIN and Tromsø planned for November.

The optical tape recorder for the archiving of Landsat historical data has been successfully installed in Frascati and its integration into the transcription archiving system is underway.

Development of the Enhanced Thematic Mapper (ETM) processing chain for Landsat-6 is progressing according to schedule, and it is being tested on Landsat-4/5 TM data.

The Fucino and Kiruna stations have regularly acquired, archived, and generated user products from, Landsat and Marine Observation Satellite (MOS) missions, while Maspalomas has resumed Spot operations in addition to its MOS and Tiros activities following an ad-hoc agreement with SpotImage.

The Earthnet Coordinated Network stations have regularly acquired and archived High-Resolution Picture Transmission (HRPT) data from NOAA-11 (afternoon) and NOAA-12 (morning). Integration of the Scanzano station into the network is in progress.

The NASA/NOAA/ESA joint project aimed at the generation of a Global Land AVHRR (Advanced Very-High-Resolution Radiometer) Data Set with 1 km resolution is now collecting data operationally at different facilities around the World.

As regards the ASEAN project, the Bangkok station is currently being upgraded to acquire and pre-process ERS-1 SAR data.

The GENIUS (Global Environment space data Network and Information User System) contract with the Swedish Space Corporation and partners continues to progress.

The Earthnet activities on the ERS-1 payload ground segment are reported under ERS-1.

EOPP

Aristoteles
The Aristoteles programme proposal has been issued by the Executive for discussion with Potential Participants and updated to take account of an offer from NASA to increase their participation.

Industrial activities continue with negotiations for extension of the Phase-A and initiation of further instrument (Gradio) pre-development activities and other supporting activities.

Meteosat second generation
The Meteosat Second Generation (MSG) programme proposal to develop the first satellite has been issued in preparation for the first Potential Participants' meeting in October 1992.

The industrial Phase-A satellite studies have passed the mid-term review. Further work is being initiated on the imager and the data-circulation antenna.

Low-Earth-orbit missions
Work continues on the definition of new instrument requirements and supporting technologies. Progress has been made in the definition of the METOP mission requirements.

Campaigns
ESA has been included as an investigator in the Hydrological Atmospheric Pilot Experiment (HAPEX), and ERS-1 SAR acquisition has taken place in the Sahel zone in Niger.

Some 50% of the SAREX image data has now been delivered. Preparations are in hand to initiate the data-analysis phase in mid-September 1992.

Proceedings of the Maestro/Agriscatt Workshop are now available (ESA WPP-31).

Polar Platform

The Polar Platform development effort has progressed, consistent with the launch date of mid-1998. A number of subsystem- and equipment-level reviews have taken place. The PPF Preliminary Design Review has been confirmed for September/October 1992.

A number of technical issues have received special attention (launch and early-orbit operations, battery management, solar array, deployment-mechanism design).

The full-scale configuration model has been used to study payload accommodation for smaller versions of the platform (see accompanying définition des nouveaux besoins en instruments et technologies de soutien. La définition des impératifs de la mission METOP avance.

Campagnes

L'ESA a été inscrite au nombre des chercheurs de l'expérience pilote Hydrologie-Atmosphère (HAPEX) et les données du SAR d'ERS-1 ont été recueillies sur le Sahel nigérien.

Il a maintenant été livré environ 50% des données d'images SAREX. Les préparatifs sont en route pour le lancement de la phase d'analyse des données à la mi-septembre 1992.

Le compte rendu de l'atelier Maestro/Agriscatt est disponible (ESA WPP-31).

Plate-forme polaire

Les travaux de développement de la plate-forme polaire ont avancé, dans l'optique d'un lancement à la mi-1998. Un certain nombre de revues ont eu lieu au niveau des sous-systèmes et équipements et la date de la revue de conception préliminaire de la PPF a été confirmée pour septembre-octobre 1992.

Divers problèmes techniques ont fait l'objet d'une attention particulière (opérations de la phase de lancement et du début du fonctionnement en orbite, gestion des batteries, réseau solaire, conception du mécanisme de déploiement).

La maquette en vraie grandeur a servi à étudier l'installation de la charge utile pour des versions plus réduites de la plate-forme (voir l'illustration du module de charge utile en trois sections).

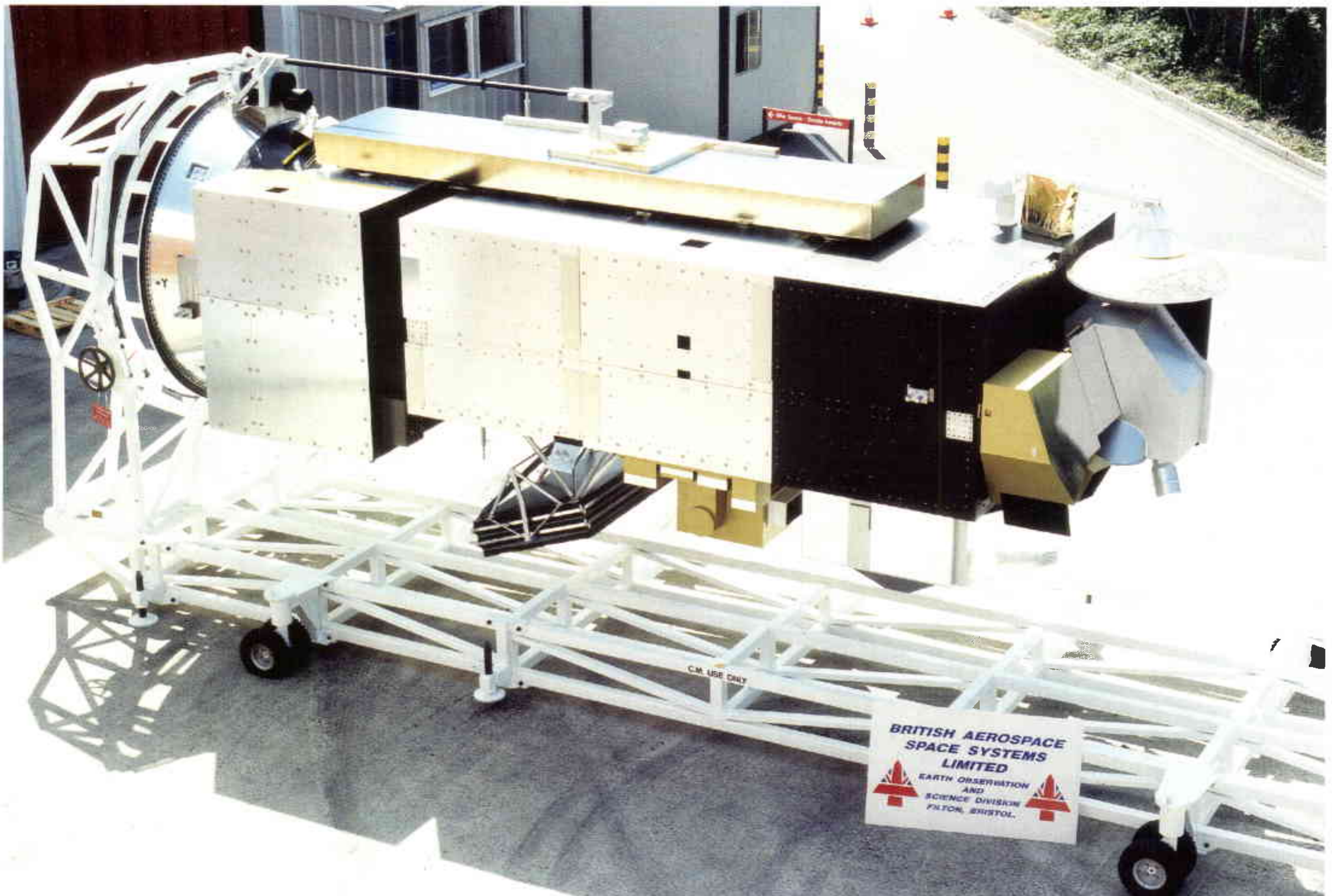
La fabrication du modèle structurel du module de servitude a commencé. La qualification complémentaire des propulseurs a été menée à bien, après l'exécution réussie d'un programme d'essais de mise à feu.

Les activités relatives au module de charge utile ont avancé, avec la définition de l'agencement du câblage et d'une reconfiguration limitée du compartiment des équipements de charge utile (PEB) ayant pour objet de minimiser les pertes électriques.

Dans le domaine assemblage, intégration et vérification (AIV), les activités ont été centrées sur la définition des essais à exécuter au cours des prochaines années, en mettant plus particulièrement l'accent sur le réseau solaire et le module de servitude.

Les livraisons de pièces EEE ont commencé pour le module de servitude et les articles à longs délais de livraison du module de charge utile sont actuellement commandés.

Plusieurs éléments de l'équipement mécanique de soutien au sol (MGSE) sont en cours de fabrication et le premier d'entre eux a été achevé.



Full-scale configuration model of the Polar Platform with three-section payload module and dummy instruments (photo courtesy of BAe, Bristol, UK) illustration of three-section payload module).

Manufacture of the structural model of the service module has started. The thruster delta qualification has been completed, following the successful completion of a firing-test programme.

The payload-module activities have progressed, with the harness layout and a limited reconfiguration in the Payload Equipment Bay (PEB) having been defined to minimise the electrical losses.

The AIV activities have concentrated on the definition of the tests to be carried out in the coming years, with special emphasis on the solar array and the service module.

Deliveries of EEE parts for the service module have started, and long-lead items for the payload module are being ordered.

Several items of Mechanical Ground-Support Equipment (MGSE) are in manufacture, the first MGSE item having already been completed.

POEM-1

Preparatory Programme

System and Instrument Phase-B Studies

The mission prime Phase-B activities are almost complete. The Baseline Design Review (BDR) of the Phase-B results was held in early June.

The BDRs for ASAR and ASCAT were initiated on 22 to 24 April, and were followed in May by those for RA-2 and MIPAS. The AMI, MERIS and GOMOS reviews were held in early June. The full BDR review cycle was completed in mid-July.

A Phase-B extension for ASAR, GOMOS and ASCAT is currently proceeding until the end of the year.

Eumetsat is supporting a review of their technical and programmatic response to the Agency's requirements for the whole meteorological package, to be held at the beginning of September with NASA/NOAA participation. NOAA/NASA recently made the decision to revert back to an existing design in order to meet the 1998 launch date.

Interface-control documents for Announcement of Opportunity (AO) instruments have been prepared and submitted to the instrument providers for comment.

MIMR instrument

The MIMR Phase-B, baselined on accommodation on-board the NASA-EOS spacecraft, progresses. A Rider has been released to study the accommodation of MIMR on-board the European Polar Platform.

Ground-segment

Phase-B proposal evaluation has been completed, and at the end of May the Agency's Industrial Policy Committee (IPC) approved the awarding of the contract to Logica.

Main Development Programme

A request for quotation for Phase-C/D of the POEM-1 Programme was released to industry in early April. Proposals for the first phase (C1), which is planned to last until April 1993, were received at the end of May. The C1 phase was kicked-off in July.

The industrial proposal for the whole Phase-C/D is in preparation. Transition from POEM-1 to Envisat is under discussion with ESA's delegate bodies.

Microgravity

The Maser-5 sounding rocket, managed by the Swedish Space Corporation, was successfully launched on 9 April 1992 from Kiruna. The quality of the microgravity environment that it provided (in terms of residual accelerations) was exceptionally good for a period of 7 min. Seven ESA experiments in the areas of fluid physics and life sciences were flown in four experiment modules.

An Advanced Glove Box developed under ESA contract by Bradford Engineering (NL), with the Brunel Institute of Bioengineering (UK) as subcontractor, was flown on the Spacelab Mission USML-1, launched on 25 June 1992. This multi-user facility allows the astronauts to perform hazardous experiments in a compartment that is physically isolated from the habitable space. In addition, the Glove Box provides supporting services such as power, illumination and TV monitoring, to experiments.

The Glove Box worked flawlessly on USML-1, the longest Spacelab mission (14 days) flown so far. All sixteen planned experiments were successfully processed, proving this ESA facility to be both very useful and versatile.

The European Retrievable Carrier (Eureca) was launched on 31 July 1992 with the Space Shuttle 'Atlantis'. The payload on this, the carrier's first mission, includes five ESA-developed multi-user facilities, referred to as the 'core payload', for experiments in materials and life sciences. Activated after checkout of the Eureca system and insertion of the Carrier into a circular 500 km-high orbit, the core payload is performing very satisfactorily.

Turning to the German D2 Spacelab mission scheduled for launch in February 1992, the ESA-developed Anthrorack for crew physiological investigations and the Advanced Fluid-Physics Module have been delivered and integrated into the Spacelab train, which has now been shipped to NASA/KSC (USA). In addition, the Anthrorack training model has been used for the systematic acquisition of physiological reference data prior to the mission.

Space Station 'Freedom'/Columbus

Manned elements

In the framework of the overall replanning of ESA Programmes, the Columbus Programme content and schedule have been updated to be consistent with the budgetary constraints. The Attached Laboratory, linked by international agreement to Space Station 'Freedom', has been kept practically unchanged in terms of its technical baseline, but the planned launch date is now the second half of 1999.

The Free-Flying Laboratory's development has been delayed to a later stage, and a new set of study activities, investigating a future European station

POEM-1

Programme préparatoire

Etudes de phase-B de systèmes et d'instruments

Les activités de phase-B 'mission' du maître d'oeuvre sont presque terminées. La revue de la conception de référence (BDR) portant sur les résultats de la phase B s'est déroulée début juin.

Les BDR des instruments ASAR et ASCAT ont été lancées du 22 au 24 avril pour être suivies en mai par celles des instruments RA-2 et MIPAS. Les revues des instruments AMI, MERIS et GOMOS ont eu lieu début juin. Le cycle complet des revues BDR s'est clos à la mi-juillet.

Les études de phase B des instruments ASAR, GOMOS et ASCAT sont actuellement prolongées jusqu'à la fin de l'année.

Eumetsat apporte son soutien à la révision de sa réponse technique et programmatique aux impératifs de l'Agence pour l'ensemble météorologique, qui doit avoir lieu début septembre avec la participation de la NASA/NOAA. Celle-ci a récemment décidé de revenir à une conception existante en vue de tenir la date de lancement de 1998.

Les documents de contrôle des interfaces des instruments qui ont répondu à l'avis d'offre de participation (AO) ont été élaborés et soumis aux fournisseurs des instruments pour commentaires.

Instrument MIMR

La phase B du MIMR, qui prend pour base de référence l'installation de cet instrument à bord du satellite EOS de la NASA, avance. Un avenant a été conclu pour l'étude de son installation à bord de la plate-forme polaire européenne.

Secteur sol

Après l'évaluation de la proposition de phase B, le Comité de la politique industrielle (IPC) de l'Agence a approuvé fin mai l'attribution du contrat à Logica.

Programme principal de réalisation

Une demande de prix a été adressée à l'industrie début avril pour la phase-C/D du programme POEM-1.

Les propositions relatives à la première phase (C1), qui doit durer jusqu'en avril 1993, ont été reçues fin mai. Le coup d'envoi de la phase C1 a été donné en juillet.

La proposition industrielle relative à l'ensemble de la phase-C/D est en préparation. Le passage de POEM-1 à Envisat est à l'examen avec les organes délibérants de l'ESA.

Microgravité

La fusée-sonde Maser-5, gérée par la Swedish Space Corporation, a été lancée avec succès le 9 Avril 1992 à partir de Kiruna. La qualité de l'environnement de microgravité qu'elle a permis de créer (du point de vue des accélérations résiduelles) fut exceptionnelle, pendant 7 minutes. Sept expériences ESA, dans les domaines de la physique des fluides et des sciences de la vie ont été mises en vol dans quatre modules expérimentaux.

Une Boîte à Gants développée sous contrat ESA par Bradford Engineering (NL), avec le Brunel Institute of Bioengineering (UK) comme sous-traitant, a été mise en vol sur la Mission Spacelab USML-1, lancée le 25 Juin 1992. Cette installation à usagers multiples permet aux astronautes d'effectuer des expériences dangereuses dans un compartiment physiquement isolé de l'habitacle. De surcroît, la Boîte à gants comporte des systèmes de servitudes tels que l'alimentation, l'éclairage et la surveillance par télévision des expériences.

Cette Boîte à gants a fonctionné de manière impeccable sur le vol USML-1, qui fut la Mission Spacelab la plus longue effectuée (14 jours). Les seize expériences prévues ont été couronnées de succès, démontrant ainsi que cette installation ESA est à la fois extrêmement utile et souple d'emploi.

Le Porte-Instruments récupérable Européen (Eureca) fut lancé le 31 Juillet 1992 à bord de la Navette Spatiale 'Atlantis'. La charge utile de ce porte-instruments, dont c'était la première mission, comportait cinq installations à usagers multiples développées par l'ESA et appelées 'noyau de charge utile', pour des expériences portant sur les matériaux et les sciences de la vie. Activé après l'essai du système Eureca et l'injection du porte-instruments sur orbite de 500 kilomètres, le noyau de charge utile se comporte de manière extrêmement satisfaisante.

Deployment of Eureca (photo courtesy of NASA)

in cooperation with Russia and the Commonwealth of Independent States, has been started. The terms for cooperation on the Mir-2 station and a Euro/CIS station will be defined over a three-year period.

The precursor-flights programme has been included in the updated Columbus Development Programme, which now covers four elements: the full development of the Attached Laboratory and the Polar Platform, the precursor flights, and the studies for the future European station.

In the revised Programme Declaration which has been issued in draft form and will be discussed shortly by the Columbus Programme Board, the four elements are included in the form of self-standing slices.

The proposed precursor flights now cover one Spacelab flight, one Eureca flight and three Mir flights, all with possible participation by national agencies in Europe, the USA, Japan or the CIS.

The industrial development activities on the Attached Laboratory continue to progress. The System Requirements Review (SRR) has been conducted successfully in June/July.

The Eurocolumbus industrial consortium was formally established on 17 June, DASA and Alenia representing the major partners. Other European industrial organisations are expected to join before the end of this year.

The ground segment for the Attached Laboratory has also been reviewed in view of the changes/budget reductions in the Programme, and work is progressing on the setting-up of the various centres and elements. Preparations for the utilisation, activities are also progressing well.

In the context of the Long-Term EXEMSI Experiment Programme activities, three men and one woman entered the isolation chambers for a two-month campaign on 7 September. The six remaining candidates will act as back-ups and Crew Interface Coordinators.

En ce qui concerne la mission Allemande D2 de Spacelab, dont le lancement était prévu en Février 1992, l'Anthrorack, étudié et réalisé par l'ESA pour les recherches de physiologie des équipages et le module de physique avancé des fluides ont été livrés et intégrés au train Spacelab, qui a été livré à la NASA/KSC (USA). De surcroît, le modèle d'entraînement Anthrorack a été utilisé pour l'acquisition systématique de données de références physiologiques avant la mission.

Station spatiale Freedom/Columbus

Eléments habités

Dans le cadre de la révision générale des programmes de l'ESA, le contenu et le calendrier du programme Columbus ont été actualisés en fonction des contraintes budgétaires. Le laboratoire raccordé, lié à la station spatiale Freedom par un accord international, est resté pratiquement inchangé quant à sa base de référence technique, mais son lancement est maintenant reporté au deuxième semestre de 1999.

Le développement du laboratoire autonome a été ajourné et une nouvelle série d'études a été mise en route au sujet d'une future station spatiale européenne réalisée en coopération avec la Russie et la Communauté des Etats indépendants. La définition des conditions d'une coopération à la station Mir-2 et à une station Europe/CEI s'étalera sur une durée de trois ans.

Le programme de vols précurseurs a été incorporé dans le programme de développement Columbus actualisé, qui comporte maintenant quatre éléments: le développement proprement dit du laboratoire raccordé et de la plate-forme polaire, les vols précurseurs et les études relatives à la future station européenne.

Ces quatre éléments figurent sous forme de tranches distinctes dans la Déclaration de programme révisée, qui a été publiée à l'état de projet et sera examinée sous peu par le Conseil directeur du programme Columbus.

Les vols précurseurs proposés à l'heure actuelle portent sur un vol Spacelab, un vol Eureca et trois vols Mir, et seraient éventuellement réalisés avec la participation des agences nationales de l'Europe, des Etats-Unis, du Japon ou de la CEI.

L'industrie poursuit ses travaux de développement du laboratoire raccordé. La revue des impératifs système a été menée à bien en juin/juillet.

Le consortium industriel EuroColumbus a été officiellement créé le 17 juin. Ses principaux partenaires, Dasa et Alenia, devraient être rejoints par d'autres industriels d'ici la fin de l'année.

Le secteur sol du laboratoire raccordé a lui aussi été révisé en fonction des modifications du programme et des réductions budgétaires, et les travaux relatifs à la constitution des différents centres et éléments suivent leur cours. Les activités préparatoires de l'utilisation sont également en bonne voie.

Dans le cadre de la campagne d'expériences de longue durée EXEMSI, trois hommes et une femme ont entamé le 7 septembre, un séjour de deux mois en enceinte confinée. Les six autres sujets de l'expérience serviront de renfort et assureront la coordination des interfaces avec l'équipage.

In Brief

More Space for European Space

On 22 October 1992, the Dutch Minister for Economic Affairs, Dr. Jacobus Andriessen, officially opened the new ERASMUS building at ESA's European Space Research and Technology Centre (ESTEC) in The Netherlands.

The new complex forms part of the ground infrastructure required to support ESA's current and future space programmes. It houses all ESA common and mission-specific activities relating to in-orbit servicing, such as rendezvous and docking operations, intra-vehicular activities (IVA), extra-vehicular activities (EVA), and robotics, and to payload utilisation. It accommodates various test beds, including the Columbus Crew Work Station test bed, the Columbus Automation test bed, and the Telescience test bed. In these laboratories, models and mock-ups of subsystems and utilities are being developed in order to define requirements, specifications and evaluation methodologies. Here, scientists and engineers also make extensive use of equipment that is already commercially available and assess its suitability for space flight.

The building also houses the Eurosim simulation facility, a robotics laboratory, a data handling laboratory and a software laboratory.

In recognition of the Dutch government's major financial contribution to the new facility, the building is named after a renowned Dutch humanist of the 15th century, Erasmus. In ESA parlance, the name ERASMUS has also been interpreted as European Robotics, Automation, Simulation and Mission Support.

Aerial view of the new ERASMUS building (foreground) at ESTEC in The Netherlands
(photo: Picture Report)

Dr. Jacobus Andriessen, the Dutch Minister for Economic Affairs, opens ESTEC's new ERASMUS building. J.-M. Luton, Director General of ESA, and M. Le Fèvre, Director of ESTEC, look on

1992 – From Munich to Granada: A Year of Progress for the European Space Endeavour

In the course of 1992, a wide range of space projects have been completed and results that are vital to the European conquest of space have been obtained. Earth observation using the ERS-1 satellite, astronomy with the Hipparcos satellite, exploration of the Solar System with the Ulysses and Giotto probes, crewed space activity with flights by two ESA astronauts, and microgravity studies with the recoverable platform Eureca have been major highlights. In short, 1992 has seen a further decisive step forward in many areas in Europe's peaceful conquest of space.

January

Excellent Performance by Hipparcos

The year got off to a fine start with the presentation in Paris, on 17 January, of the first results obtained by the star-mapping satellite Hipparcos. The satellite had been in orbit for two and a half years, sending back more than a billion bits of high-quality information each day since the start of scientific operations towards the end of 1989. By the end of this year, sufficient information will have been gathered to achieve the specified aim of estimating the positions and movement of some 120 000 stars in the Galaxy with an accuracy 100 times greater than is possible using the best existing terrestrial telescopes. Hipparcos may, however, even go one better, as it is about to commence an extension of its mission through to 1994.

Two Flights by ESA Astronauts in Less Than A Year

1992 was also a year in which preparations for crewed missions onboard Columbus, the European Attached Laboratory forming part of the International Space Station, picked up speed, with two ESA astronauts undertaking missions in orbit within a few months of each other – a record for the Agency.

The first of those missions was also the third time that an ESA astronaut has gone into space. This was the flight of Ulf Merbold onboard the Space Shuttle 'Discovery', from 22 to 30 January, for the first mission of IML-1, the International Microgravity Laboratory. Over an eight-day period, Ulf and his fellow crew members carried out 42 experiments in the European-built Spacelab carried in the Shuttle's cargo bay. Half of those experiments came from Europe. ESA also provided two large experiment facilities for the mission: 'Biorack', carrying seventeen life-sciences experiments, and the 'Critical-Point Facility', accommodating four experiments for the study of matter in the very special 'critical fluid' state when it has both liquid and gaseous properties. The experiments were very successful, a host of results were obtained, and the next international mission in the series, IML-2, is planned for early 1994.

Claude Nicollier made the second flight by an ESA astronaut, onboard the Space Shuttle 'Atlantis', from 31 July to 8 August (Eureca item below contains further details).

Outstanding Results from ERS-1

In the Earth-observation field, the ERS-1 satellite, which has been in operation since late January, is proving to be highly successful. ERS-1 and its associated ground-support segment constitute the most complex space system ever devised in Europe. Some 300 000 high-resolution pictures have already been taken of the Earth's land masses, oceans and polar-ice regions.

Work was soon to begin on building ERS-2, the satellite that will take over from ERS-1 in 1995 and that will be carrying an additional instrument for observing the Earth's ozone layer.

February

A First in Space History

On 8 February, matters took a decisive turn for the Ulysses probe when it was moved out of the plane in which the planets move (the 'ecliptic plane') by exploiting the force of Jupiter's gravitational pull, to create a space first. The probe is now exploring totally new worlds; it is on the way to fly over the Sun's southern pole in the summer of 1994.

The encounter with Jupiter also provided fascinating new data on the giant planet's very active environment. Ulysses has shown that Jupiter's magnetosphere stretches for an extraordinary distance towards the Sun, whilst its radiation belts extend to lower latitudes than is the case for the Earth. The probe has also measured currents of a billion Ampères in Jupiter's polar aurorae, and has established that Io, the planet's largest satellite, is now less active than during previous space-probe fly-bys.

March

A First for Europe On-board 'Atlantis'

Another crewed mission to which ESA contributed this year was the flight of the Atlas laboratory onboard Space Shuttle 'Atlantis'. From 24 March to 2 April, Dirk Frimout, the first Belgian astronaut, and an ESA scientist, took part in this first of a series of ten missions to study the Sun's influence on the Earth's atmosphere and climate. In addition to Spacelab elements, Europe contributed four experiments for monitoring the tiny variations in the Sun's luminosity over its eleven-year cycle of activity, together with changes in atmospheric properties.

The mission was a great success. Hundreds of billions of bits of invaluable data about our planet were collected and the Solcon radiometer established a major first: European scientists were able for the first time to control their instruments in space directly from ESTEC, ESA's Space Research and Technology Centre at Noordwijk in The Netherlands. This gave them a first taste of the working methods that will be used for Columbus missions.

International Space Year
The first high point of International Space Year was a European Conference in Munich, jointly organised by ESA, DARA and the EEC, with the theme 'Space in the Service of a Changing World'. The Conference was attended by some 2000 space professionals, while the accompanying public exhibition attracted several thousand visitors.

April

A Successful Year for Ariane
The firing of the 50th Ariane launcher since the inaugural flight of Ariane-1 on 24 December 1979 was a very moving and symbolic moment. This 50th flight on 15 April, from Europe's own space port in Kourou, French Guiana, proceeded without incident. The European launcher is continuing to achieve outstanding results.

At the same time, preparations for the future are progressing with Ariane-5, which this year reached the mid-point in its development schedule. The first Ariane-5 launch is currently planned for October 1995.

May

Astronauts: Further Progress
In May, Mr Jean-Marie Luton, ESA's Director General, announced the names of six new ESA Candidate Astronauts who, following basic training, will join the ranks of the European Astronaut Corps, in preparation for the long-duration crewed missions of the next century. This represented a major step forward for ESA, which previously had only three qualified astronauts.

The Earth Summit
ESA was invited to attend the 'Earth Summit' which took place in Rio de Janeiro, Brazil, in May–June. At the Summit, ESA discussed the contributions that European environmental satellites will make, and ERS-1 images and data were widely presented.

Olympus, ESA's pre-operational telecommunications satellite, also played a part in the proceedings. A network of Very Small Aperture Terminals (VSATs) was used to transmit data and even to provide video-conferencing facilities between Rio and Europe. VSAT technology is proving to be a very promising communications option for developing countries, as well as Central and Eastern Europe.

July

Giotto – A Model of Efficiency
The second encounter of the year came when Giotto, the ESA probe launched seven years ago, was reactivated to fly-by Comet Grigg-Skjellerup on 10 July – representing a new lease of life for a craft whose primary mission was completed more than six years earlier.

In 1986, Giotto passed within 600 km of Comet Halley and sent back to Earth the first pictures of the cometary nucleus and the first in-situ measurements of its atmosphere. This year, flying past a very different comet at a distance of 200 km, the probe has supplied 500 million bits of unique information, thus giving a fresh boost to cometary science, to which it had already made such a vital contribution.

August

Eureca
This mission was of crucial importance to the Agency, ESA Astronaut Claude Nicollier's main task being to help to deploy Eureca, the first European recoverable satellite and the largest ever developed by the Agency (4.4 t at launch), from the Shuttle. Eureca offers unique capabilities for long-duration experiments (8 to 10 months) under exceptionally good microgravity conditions (1/100 000th of terrestrial gravity), coupled with the ability to return samples to Earth.

Eureca has been designed to fly five times over a ten-year period. On this occasion, it had onboard 15 multi-purpose instruments that allowed scientists to perform 50 different experiments, including: crystal growth, study of living organisms, X-ray observation of the Sun and sky, and testing of a new type of space motor based on ionic propulsion.

One very sucessful experiment involved establishing a link between two ESA orbiting satellites for the first time, in this case between Eureca and the Agency's geostationary telecommunications satellite Olympus. Using the Inter-Orbit Communication (IOC) experiment, Eureca is able to communicate 70% of the time with ESA's Maspalomas ground station in the Canary Islands (E) via Olympus, which acts as a relay. This highly successful demonstration is paving the way for ESA's Artemis and DRS satellite projects.

November

EXEMSI
In concluding the long list of major events that have left their mark in 1992, it is perhaps appropriate to mention the four 'Exemsinauts' who emerged on 6 November after spending 60 days in a 70 m^3 isolation chamber. The purpose of this experiment, conducted at DLR's Institute for Aerospace Medicine in Cologne (D), was to study the physiological and psychological problems with which crews will have to contend in the future when living and working within the narrow confines of a Space Station.

ESA PRESS RELEASE
Granada, 10 November 1992

European Space Agency Given Mandate for Coming Years

The Council of the European Space Agency, meeting at Ministerial Level in Granada, Spain, on 9 and 10 November 1992, under the Chairmanship of Professor Hubert Curien, the French Minister for Research and Space, gave ESA a wide-ranging mandate to continue with all existing programmes.

The Ministers, representing the 13 Member States of the Agency, Associate Member Finland, and Canada, reaffirmed the commitment made at the Munich Meeting to the continuity and strengthening of European space policy, while adapting the Agency's strategy for its future space programmes to the changing political and economic circumstances.

All Member States are strongly in favour of strengthening the Agency's activities in the pursuit of a greater understanding of the Earth's environment and the problems that all countries face in this domain. Envisat-1, a remote-sensing mission dedicated to the science and processes of the environment, thus ensuring continuity of the invaluable data provided by the Agency's ERS-1 and ERS-2 satellites, received full support. Preparatory activities will go ahead for the operational climate-monitoring mission Metop-1, planned for launch in the year 2000, to be developed in cooperation with Eumetsat, and which will represent a significant contribution to the Eumetsat programme for long-term monitoring of 'Planet Earth'. A start will be made in 1993 on a second-generation Meteosat system, again to be developed in close collaboration with Eumetsat, the first launch being planned for 1999.

In pursuing the In-Orbit Infrastructure programmes, the development of the Columbus Attached Pressurised Module (APM) has now been given the go-ahead. The Agency will negotiate the exploitation costs of the International Space Station with NASA, aiming to achieve a firm ceiling, within which a significant portion of the Agency's contribution will be made 'in kind'. This could include such services as the Assured Crew-Return Vehicle (ACRV), the Automated Transfer Vehicle (ATV) using the Ariane launcher, and the Data-Relay System (DRS).

Concerning Hermes, the decision was taken to continue with the orientation of the programme towards greater and deeper cooperation with Russia, to arrive at a crewed space transportation system developed from Hermes. The programme will be reviewed in 1995.

The decision was taken to go ahead with the Data-Relay Satellite, DRS-1.

These developments, together with an assessment on the operational uses of the DRS, will be the subject of a major review in February 1995.

Within the Columbus Programme, means to provide full funding for the APM laboratory will be clarified, with specific measures being taken over the next few years to align development with the financial resources available. A five percent cut in APM costs was accepted.

The problems faced by several Member States following the financial re-alignments of the last few months were fully discussed, and the Agency must provide an equitable solution of an interim nature before the end of the year.

The Ministers were enthusiastic about the synergy existing with the CEC on Earth-observation questions, Eutelsat and Eumetsat. They welcomed what had been achieved with ESA's international partners, particularly the USA, Russia and Japan, and they look for an intensification and expansion of relations.

Relations with Russia received particular attention, with emphasis on joint studies in the areas of in-orbit infrastructures and associated communications, manned transportation systems and missions of European astronauts to the Mir station. Possible cooperation with other former USSR countries might be considered.

ESA now has clear policies to follow for the coming years, and a further review at Ministerial Level will take place in 1995.

Aerospace Students Design Satellite

Twenty students from 10 European countries participated in a two-week workshop on designing and building satellites, as a practical supplement to their university studies.

The European Association of Space Students (Euroavia) initiated and organised the educational workshop, with the support of ESA and leading European aerospace companies. The event took place at ESTEC in the Netherlands from 3 to 14 August.

The workshop focused on designing a scientific satellite named Ecowatcher that could undertake a mission that complements ESA's future Polar Orbiting Earth Mission (POEM-1) in the observation of the Earth and its environment. Using its main instrument, the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (Sciamachy), Ecowatcher would monitor processes in the Earth's atmosphere, from a 41°-inclination orbit. The data gathered on trace gases in the lower layers of the atmosphere would allow scientists to improve their understanding of the atmospheric chemistry in the sub-tropical and tropical regions of the Earth, the two regions that most influence the planet's climate.

The workshop participants were selected by a jury of technical experts based on an essay on space technology that each student submitted. Senior specialists from ESTEC and the sponsoring aerospace companies advised the students throughout the workshop.

Euroavia was founded in 1959 and is run exclusively by aerospace students. Its goals are to promote and develop European cooperation in the aerospace industry. It has 24 chapters in 13 European countries.

COMPTEL Detects Radiation from Far in Universe

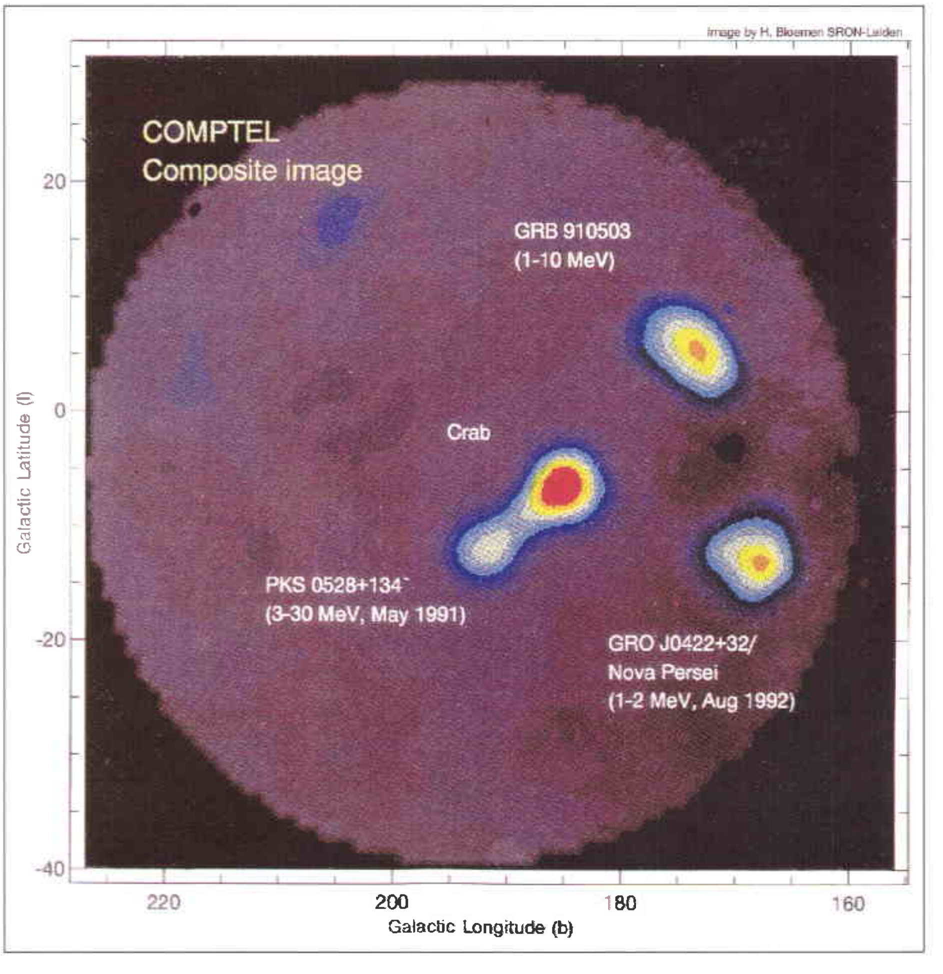
COMPTEL, a telescope flying aboard the Compton Gamma-Ray Observatory (CGRO), has detected medium-energy gamma-ray emissions from sources ranging in distance from 1 AU, i.e. the Sun, to the most distant class of objects in the Universe, i.e. quasars. These sources were detected using a number of different scientific observing modes, such as the double-scatter telescope, the burst and the solar neutron modes. ESA's Space Science Department has played a major role in the development of COMPTEL.

The accompanying figure is a composite skymap covering the region of the galactic anticentre. It is constructed from several observations made by the COMPTEL experiment during an all-sky survey which lasted 18 months.

Several sources are evident. They are a representative sample of the classes of objects that COMPTEL can observe. The intense source near the centre of the figure is the Crab pulsar and nebula. Slightly below the Crab, at (l,b = 191°,−11°), is the quasar PKS 0528+134. Toward the top of the figure, at (l,b = 172°,+6°), is the cosmic gamma-ray burst of 3 May 1991. Toward the right edge, at (l,b = 166°,−12°), is the hard X-ray/gamma-ray transient GRO J0422+32, which the Compton Observatory studied as a target of opportunity in August 1992.

The energetic solar flares of June 1991, which occurred when the Sun (at (l,b = 180°,−10°)) was aligned with the direction of the galactic anticentre, are not included in this composite map. COMPTEL detected the solar flares in both gamma rays and neutrons.

The second phase of the CGRO mission, consisting of deeper searches in interesting regions of the sky, is already underway.



Composite skymap of galactic anticentre region, from observations made by COMPTEL

Hipparcos Provides Improved Data on Stars

The astrometry satellite Hipparcos has completed 32 months of scientific data collection. The reduction of the data gathered in the first 20 months has now been completed.

It has resulted in considerable improvements in position and parallax estimates for the 120 000 programme stars over the estimates derived from the first 12 months of mission data. High-quality estimates of distance are now available for more than half of the stars. For the first time, estimates of the stellar motions have also been determined.

The Tycho Input Catalogue of star positions has been updated using data derived from the Hipparcos satellite's star mappers. More than one million stars are recognised in the Tycho data processing, and a preliminary comparison with the main mission results indicates that the knowledge of the typical positions of those stars has already been improved to better than 0.1 arcsecond.

Over the summer of 1992, several problems with the Hipparcos gyroscopes arose and scientific observations were suspended for ten weeks between August and October. The operational software both on the satellite and on the ground was greatly modified to allow operations to continue using only two gyroscopes instead of three.

Attitude Sensor Package Tested in Space

The Space Shuttle 'Columbia' (STS-52), launched on 22 October 1992, carried ESA's Attitude Sensor Package (ASP) as part of its payload. The purpose of the experiment was to expose unique spacecraft attitude sensors to actual space conditions to demonstrate the performance and accuracy of the instruments.

The ASP experiment consisted of three different spacecraft attitude sensors. The primary instrument, the Modular Star Sensor, is the first ESA solid-state star sensor to operate in space. The other two instruments were the Low Altitude Conical Earth Sensor and the Yaw Earth Sensor. All three were built by Officine Galileo (Italy) for ESA's In-Orbit Technology Demonstration Programme.

The ASP experiment was operated for 16 orbits during the ten-day mission. The simultaneous flight of the three sensors will allow improvements in their accuracy through mutual cross-calibration.

ESA's In-Orbit Technology Demonstration Programme provides flight opportunities to verify in space the performance of advanced technologies that cannot be properly tested on ground.

Crew Begins 60-Day Isolation Experiment

On 7 September 1992, a crew of four entered a pressure chamber and laboratory in a deep-diving facility to live and work in isolation for 60 days. The study, which is part of the Experimental Campaign for the European Manned Space Infrastructure (EXEMSI'92), simulates a long-duration, manned mission on a small space station.

One of the main objectives is to observe how a small, mixed group (in this case, one woman and three men) behave when isolated in a confined space to perform an experimental scientific programme that is similar to the activities that would be undertaken in a low Earth orbiting space station. Physiological studies and psychological tests, for example to examine individual performance under stress, will be conducted. Studies of nutrition and food supply management and the use of remote medical assistance or 'telemedicine', will also be undertaken.

The experiment is being conducted in the deep-diving facility at DLR, in Cologne, Germany. The crew was selected from among 150 candidates, using criteria similar to those used for selecting astronauts. Four other crew members were selected to act as the 'ground' support team, in particular to coordinate the interfaces with the confined crew. Two others are stand-by crew members.

EXEMSI'92 crew entering lab and habitat parts of isolation chamber. From left to right: Matthieu Roulet (France), Anita Vestin (Sweden), Clemens Lothaller (Austria), and Hildo Krop (The Netherlands)
(photo: DLR/ESA)

Atlas-1 Crew Visits ESTEC

In September, five of the seven-member crew of the Atmospheric Laboratory for Applications and Science (Atlas-1) mission, and several members of the ground support team visited ESTEC in the Netherlands. Atlas-1 flew onboard the Space Shuttle 'Atlantis' (STS-45) in late March 1992. The crew included Dirk Frimout, an ESTEC staff member and the first Belgian in space. The mission was led by Charles Bolden who has since been appointed Assistant Deputy Administrator of NASA.

The Atlas-1 mission used 12 different experiment facilities, mounted in the ESA-developed Spacelab in the Shuttle's cargo bay, to conduct investigations in atmospheric science, solar physics, space plasma physics and astronomy, with excellent results.

Atlas-1 crew in a mock-up of the Columbus Attached Laboratory during a visit to Noordwijk Space Expo in the Netherlands. From left to right: D. Frimout (payload specialist), C. Chappell (alternate payload specialist), B. Lichtenberg (payload specialist), C. Bolden (commander), M. Lampton (alternate payload specialist), D. Leetsma (mission specialist), B. Duffy (pilot)

ESA and Russian Space Agency To Continue Cooperation

On 12 October, Jean-Marie Luton, Director General of ESA, and Yuri Koptev, Director General of the Russian Space Agency (RKA), signed a joint statement on space cooperation. The accord was the result of a series of meetings between ESA and various Russian entities, which have been held under the terms of the Cooperation Agreement on Space reached by ESA and the Government of the USSR in April 1990.

The two agencies will 'actively pursue the cooperation in which they have been engaged for several years in the fields of space science, microgravity research and Earth observation'. In order to achieve shared objectives, they will also evaluate the prospect of joint development and operation of elements of an inhabited in-orbit infrastructure and a space transportation system.

The two parties agreed to finalise discussions about flights by ESA astronauts on the Mir station and to establish cooperation on crewed flights in the near future. In addition, they agreed to continue discussions regarding commercial launch systems and each agency's interests.

J.-M. Luton, Director General of ESA, and Y.N. Koptev, Director General of the Russian Space Agency (RKA), signing the declaration on intended future cooperation

ESA Astronaut Returns Home

Following his successful flight on the Space Shuttle 'Atlantis' (STS-46) in July, ESA astronaut Claude Nicollier returned to Switzerland, his home country, for several days in September. During the course of the mission, Dr. Nicollier was heavily involved in the deployment of ESA's retrievable carrier 'Eureca'. Dr. Nicollier will report in detail on his flight in the next issue of the ESA Bulletin.

Swiss authorities, represented by Federal Councillor Mr. Delamuraz, welcome ESA astronaut Claude Nicollier and his wife Susana at the Geneva airport
(photo: Alain Morvan)

1967 - 1992: 25 ans de succès à l'ESOC

Introduction

Depuis sa création le 8 septembre 1967, le centre d'opérations spatiales de l'Agence spatiale européenne, situé à Darmstadt en République fédérale d'Allemagne, a contrôlé les 30 satellites lancés par l'Agence dans tous les domaines de l'activité spatiale et appuyé 14 missions pour des agences ou des instituts nationaux. Ses 25 années d'existence ont été jalonnées de plusieurs premières et de sauvetages inespérés, dont le dernier en date était celui du satellite de télécommunications, Olympus.

De l'ESDAC à l'ESOC

L'ESDAC, le prédécesseur de l'ESOC, prit ses quartiers en 1963 dans un bureau du Deutsche Rechenzentrum dans la Rheinstrasse, comptant alors trois membres du personnel. Son directeur avait un nom prédestiné, Dr. Stig Comet, préfigurant peut-être le destin de l'ESOC tourné vers les corps célestes. L'année 1964 vit un nouveau déménagement vers l'immeuble de la Deutsche Buchgemeinschaft dans la Havelstrasse et marquait le début d'une lente évolution vers un effectif qui devait atteindre 53 personnes en 1967 lorsque le Dr. Gerhard Stoltenberg, Ministre allemand de la recherche scientifique signa avec le Professeur Pierre Auger, directeur de l'ESRO (European Space Research Organisation) l'accord créant le centre européen d'opérations spatiales à Darmstadt.

La pose de la première pierre de ce qui s'appelait encore l'ESDAC eut lieu en 1965. Les travaux, menées sous la direction de M. Harry Gould, détaché par le gouvernement britannique, se terminèrent en 1968. Le premier bâtiment de l'ESOC resta isolé jusqu'en 1971 avant que le centre de contrôle des opérations (l'actuel bâtiment E) ne soit construit en 1972, suivi en 1974 par le centre informatique de l'ESA et le centre des opérations de Météosat. Un nouveau bâtiment s'élève depuis 1990 qui porte ainsi la surface construite de 200 m^2 à l'origine à 29 934 m^2.

Parallèlement les effectifs passaient de 95 employés permanents à 324 aujourd'hui auxquels s'ajoutent environ 700 employés de sociétés contractantes.

Ving-cinq années d'opérations ininterrompues

En 1968 les 42 membres du personnel spécialisés dans le contrôle des satellites sont transférés de l'ESTEC à Noordwijk vers l'ESOC, à temps pour le premier lancement d'un satellite de l'ESRO le 17 mai 1968, ESRO-2 (IRIS). Aujourd'hui, l'ESOC détient un palmarès éloquent. Ce centre d'opérations de l'ESA unique en Europe a suivi:
— quinze satellites scientifiques
— huit satellites de télécommunications
— cinq satellites météorologiques

Aerial view of the ESOC facility in Darmstadt, Germany

ESOC staff members celebrating the 25th anniversary

— un satellite de télédétection
— une plateforme récupérable
dont:
— sept en orbite basse
— cinq en orbite hautement excentriques ou géosynchrones
— seize en orbite géostationnaire
— deux lors de vols interplanétaires.

Actuellement, le centre européen d'opérations spatiales contrôle 16 satellites, soit directement de Darmstadt, soit à partir des stations au sol de l'ESA. Vingt-quatre heures sur vingt-quatre les cinq salles de contrôle sont occupées par des équipes qui se relayent toutes les huit heures. La grande salle de contrôle est réservée aux phases de lancement et de mise à poste et aux opérations de sauvetage, si nécessaire. A cela s'ajoutent les salles d'ordinateurs, les réseaux de télécommunications OPSNET et ESANET ainsi que la salle de contrôle de la configuration au sol.

Un centre ouvert 24 heures sur 24
M. Jean-Marie Luton, Directeur général de l'Agence spatiale européenne, a retenu trois traits caractéristiques de l'établissement de Darmstadt:
— c'est le seul établissement ouvert 24 heures sur 24 tout au long de l'année, et cela depuis son inauguration;
— c'est le seul specialisé dans le fonctionnement et la surveillance des satellites de l'Agence. La variété de ses 31 missions montre son savoir-faire;
— enfin, l'ESOC réalise un mélange particulier de conservatisme et d'audace.

''C'est dans les situations imprévues que l'expertise et la compétence accumulée en 25 ans se sont manifestées et se sont révélées indispensables...'', a poursuivi Jean-Marie Luton dans un discours adressé à l'ensemble du personnel le 5 octobre 1992 à l'ESOC. Il a également évoqué les futures missions scientifiques et autres qui demanderont à tous les établissements et donc à l'ESOC de nouveaux trésors d'ingénuosité avant la fin de la décennie.

Plus de deux cents invités du monde industriel européen et des autorités allemandes s'étaient joints aux quelque 800 personnes présentes sur le site pour célébrer 25 ans de coopération européenne et de réussite technique.

Les invités ont tout d'abord écouté l'orchestre européen de musique de chambre (European Wind Soloists) dans un octuor de Beethoven. Le choix s'était porté sur cet orchestre de chambre dérivé de l'orchestre de jeunes de la Communauté européenne (European Community Youth Orchestra) comme symbole de l'unité européenne et de l'engagement de jeunes gens envers l'Europe.

La cérémonie s'est poursuivie par un sketch interprété par trois acteurs du groupe de théatre de l'ESOC, rappelant, sur le mode humoristique, à quel point la vie d'un ingénieur chargé des opérations était dure ... autrefois. Nuits courtes, services longs et dévouement sans compter auraient été, selon nos trois compères, le pain quotidien des pauvres contrôleurs d'autrefois. Les rires du public ont montré que leur lot d'aujourd'hui n'avait guère changé.

M. Félix García-Castañer, Directeur de l'ESOC, a tenu, à cette occasion, à rendre un hommage particulier au personnel permanent et aux contractants des entreprises industrielles pour leur travail. Vingt-huit personnes étaient particulièrement à l'honneur puisqu'elles ont participé à l'édification de l'ESDAC, puis de l'ESOC depuis les premiers jours.

Après un film sur les missions conduites par l'ESOC pour l'ESA, tous les participants ont écouté l'hommage du Prof. Wild, Directeur de la DARA (Deutsche Agentur für Raumfahrt Angelegenheiten) et de M. Metzger, maire de Darmstadt.

Former and present directors of ESOC at ESOC's 25th anniversary ceremony. From left to right: G. Formica, U. Montalenti, F. García-Castañer, G. Metzger (Mayor of Darmstadt), R. Steiner, and K. Heftman (photo: Studio Smith)

Focus

Mount Bosavi, Papua/New Guinea

The tropical rain forest of central Papua/New Guinea. The prominent concentric feature near the upper right corner suggests a heavily eroded volcanic cone, with a caldera: it is Mount Bosavi, which rises more than 2000 m above the surrounding plain.

The ERS-1 SAR uncovers huge lava flows running eastwards. It is possible to distinguish two different periods, one on top of the other. Some small ring craters and holes of several hundred metres diameter on the cone's surface may have been caused by explosions of trapped gas. Flow patterns quite similar to those found on glaciers are visible. There is a further volcanic feature near the lower right corner, with lava-flows that are short and concentric.

The mountain ranges to the north are limestone. Drainage is towards the east, the Hegidio River in the north, Guari and Kanuwe in the south. With the exception of some small settlements visible as bright spots in a few places, no human activity (plantations, logging, etc.) is visible.

- Data acquisition: Alice Springs (Australia), orbit 4255, 9 May 1992 0:42:28 (UTC)
- Data processing: ESA/Earthnet, ESRIN, Frascati (Italy)
- Pixel spacing: 12.5 m
- Location of image centre:
  Latitude: 6°00′ S
  Longitude: 143°10′ E

Earth

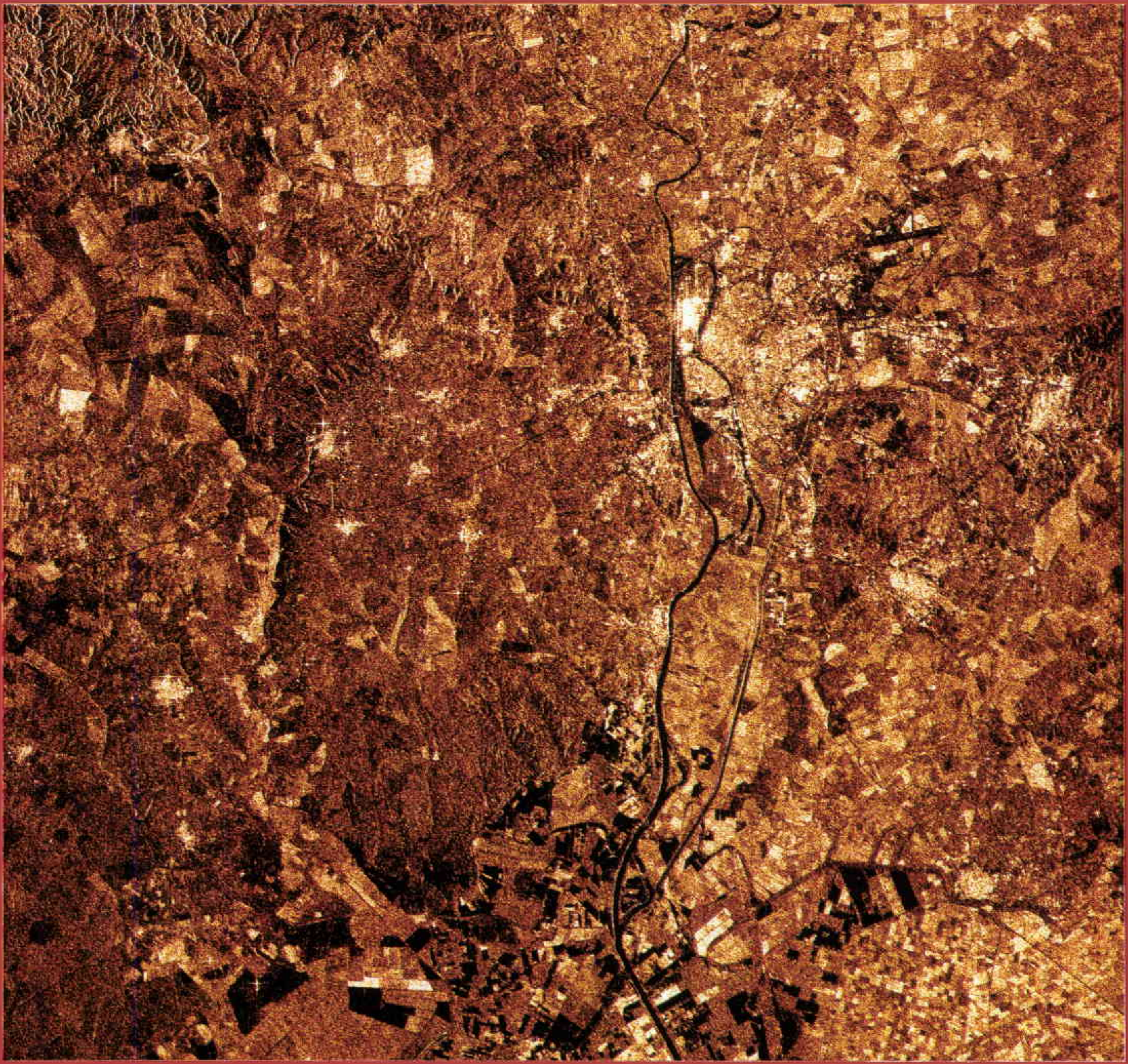
Seville, Spain

This image shows an area some 50 km by 50 km around the city of Seville. Patterns of buildings, concentric rings of avenues, and roads radiating towards the hinterland, are easily identifiable. The site of Expo'92 is clearly visible as an agglomeration of extremely strong microwave scatterers (very bright points), consisting mainly of metallic structures.

Down the Guadalquivir River, the valley opens into a vast agricultural area, the Marisma. Its fields are coded in distinct grey levels, suggesting different types of agriculture. The black areas are rice fields growing in water. The medium-grey level can be associated with fields of sunflowers, but also fruit-trees and vineyards. The bright fields could be cotton, which is the most advanced crop at the time of year when the image was taken.

The rather homogenous, hilly zone to the west of the Guadalquivir River is the Donana, a nature reserve.

- Data acquisition: Fucino (Italy), orbit 5020, 1 July 1992
- Data processing: ESA/Earthnet, ESRIN, Fracati (Italy)
- Pixel spacing: 12.5 m
- Location of image centre:
  Latitude: 37°20′ N
  Longitude: 6°05′ W



Publications

The documents listed here have been issued since the last publications announcement in the ESA Bulletin. Requests for copies should be made in accordance with the Table and using the Order Form inside the back cover of this issue.

ESA Journal

The following papers have been published in ESA Journal Vol. 16, No. 3:

INFLUENCE OF FLUX RESIDUES AND CONFORMAL COATINGS ON THE SURFACE RESISTANCE PROPERTIES OF SPACECRAFT CIRCUIT BOARDS
P.-E. TEGEHALL & B.D. DUNN

AN EVALUATION OF SOLAR-PROTON EVENT MODELS FOR ESA MISSIONS
C. TRANQUILLE & E.J. DALY

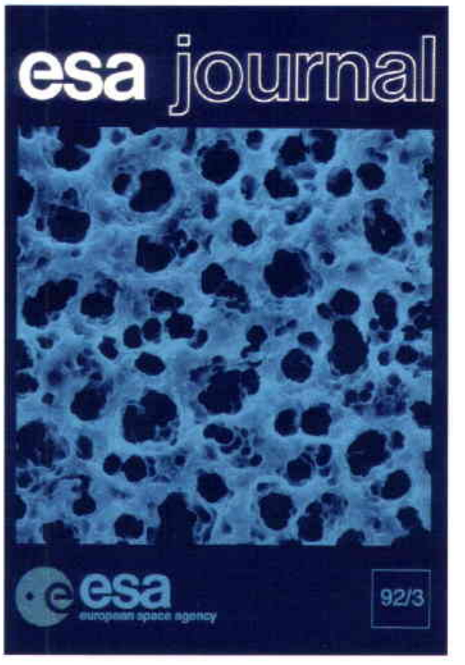
MODELLING AND CALCULATION OF ATMOSPHERIC ATTENUATION FOR LOW-FADE- MARGIN SATELLITE COMMUNICATIONS
E. SALONEN ET AL.

DIGITAL AUDIO BROADCASTING BY SATELLITE UTILISING TRELLIS-CODED QUASI-ORTHOGONAL CODE DIVISION MULTIPLEXING
R. DE GAUDENZI

COLLISION RATES AND IMPACT VELOCITIES FOR BODIES IN LOW EARTH ORBIT
A. ROSSI & P. FARINELLA

ORBIT STRATEGIES AND NAVIGATION NEAR A COMET
M. NOTON

A NEW LATCHING MECHANISM
F. PANIN



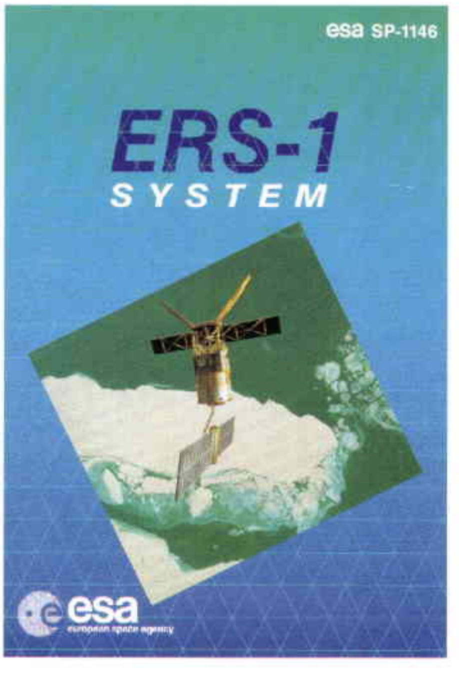
ESA Special Publications

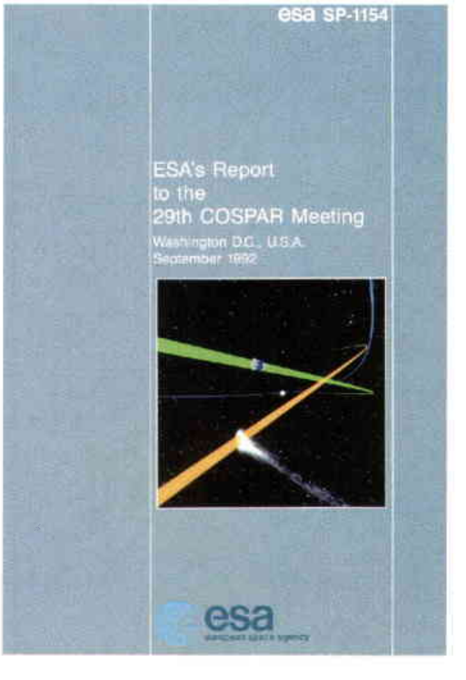
ESA SP-346 // PRICE 75 DFL
PROCEEDINGS OF THE 26 TH ESLAB SYMPOSIUM ON THE STUDY OF THE SOLAR-TERRESTRIAL SYSTEM, 16–19 JUNE 1992, KILLARNEY, IRELAND
ED. J.J. HUNT

ESA SP-1146 // PRICE 35 DFL
THE ERS-1 SYSTEM
EDS. P. VASS & B. BATTRICK

ESA SP-1153 VOLS A & B // PRICE 75 DFL PER VOL
IUE – ULDA ACCESS GUIDE NO. 4
ACTIVE GALACTIC NUCLEI
COMPILED BY T. J.-L. COURVOISIER & S. PALTANI

ESA SP-1154 // PRICE 50 DFL
ESA's REPORT TO THE 29TH COSPAR MEETING, WASHINGTON DC, USA
ED. W.R. BURKE





ESA ISY-1 (3 VOLS) // PRICE 270 DFL
PROCEEDINGS OF CENTRAL SYMPOSIUM OF THE ISY CONFERENCE – REMOTE SENSING FOR GLOBAL CHANGE AND ATMOSPHERE & GLOBAL FORECASTING, 30 MARCH–4 APRIL 1992, MUNICH, GERMANY
EDS. T.D. GUYENNE & J.J. HUNT

ESA ISY-2 // PRICE 90 DFL
PROCEEDINGS OF SATELLITE SYMPOSIA 1 & 2 OF THE ISY CONFERENCE – NAVIGATION & MOBILE COMMUNICATIONS; IMAGE PROCESSING, GIS & SPACE-ASSISTED MAPPING, 30 MARCH–4 APRIL 1992, MUNICH, GERMANY
EDS. T.D. GUYENNE & J.J. HUNT

ESA ISY-3 // PRICE 70 DFL
PROCEEDINGS OF SATELLITE SYMPOSIUM 3 OF THE ISY CONFERENCE – SPACE SCIENCES WITH PARTICULAR EMPHASIS ON HIGH-ENERGY ASTROPHYSICS, 30 MARCH–4 APRIL 1992, MUNICH, GERMANY
EDS. T.D. GUYENNE & J.J. HUNT

ESA ISY-4 // PRICE 90 DFL
PROCEEDINGS OF SATELLITE SYMPOSIUM 4 OF THE ISY CONFERENCE – COLUMBUS EIGHT (COSY-8): UTILISATION OF EARTH ORBITING LABORATORIES, 30 MARCH–4 APRIL 1992, MUNICH, GERMANY
EDS. T.D. GUYENNE & J.J. HUNT

ESA Annual Report

ESA ANNUAL REPORT 1991 // NO CHARGE
(AVAILABLE IN ENGLISH OR FRENCH)
EDS. N. LONGDON & T.D. GUYENNE

ESA Brochures

ESA BR-81 // NO CHARGE
SPAIN – SUCCESS STORY IN SPACE
ED. N. LONGDON

ESA BR-82 // 25 DFL
ECS – EIGHTH YEAR IN ORBIT
ED. W.R. BURKE

ESA BR-86 // NO CHARGE
L'ESPACE EUROPEEN . . . À DES FINS EXCLUSIVEMENT PACIFIQUES
ED. N. LONGDON

ESA BR-90 // NO CHARGE
25 YEARS OF ESOC
ED. N. LONGDON

ESA HSR-2 // PRICE 25 DFL
ESRO's FIRST SCIENTIFIC SATELLITE PROGRAMME: 1961–1966
ED. A. RUSSO

ESA Newsletters

EARTH OBSERVATION QUARTERLY NO. 39, OCTOBER 1992 (ENGLISH OR FRENCH)
(NO CHARGE)
EDS. N. LONGDON & T.D. GUYENNE

ECSL NEWS NO. 9, JUNE 1992
(NO CHARGE)
EDS. N. LONGDON & T.D. GUYENNE

ECSL NEWS NO. 10 SEPTEMBER 1992
(NO CHARGE)
EDS. N. LONGDON & T.D. GUYENNE

PREPARING FOR THE FUTURE, VOL. 2, NO. 3, SEPTEMBER 1992
(NO CHARGE)
EDS. N. LONGDON & S. HEERD

ESA Training Manuals

ESA TM-16 // PRICE 40 DFL
XRONOS – A TIMING ANALYSIS SOFTWARE PACKAGE. USER'S GUIDE VERSION 3.00
EDS. L. STELLA & L. ANGELLI

ESA Scientific & Technical Reports

ESA STR-235 // PRICE 25 DFL
ASSESSMENT OF COLUMBUS PAYLOAD OPERATIONS CAPABILITIES BY SCHEDULING WITH THE MARS SYSTEM
ED. B. CALVIGNAC

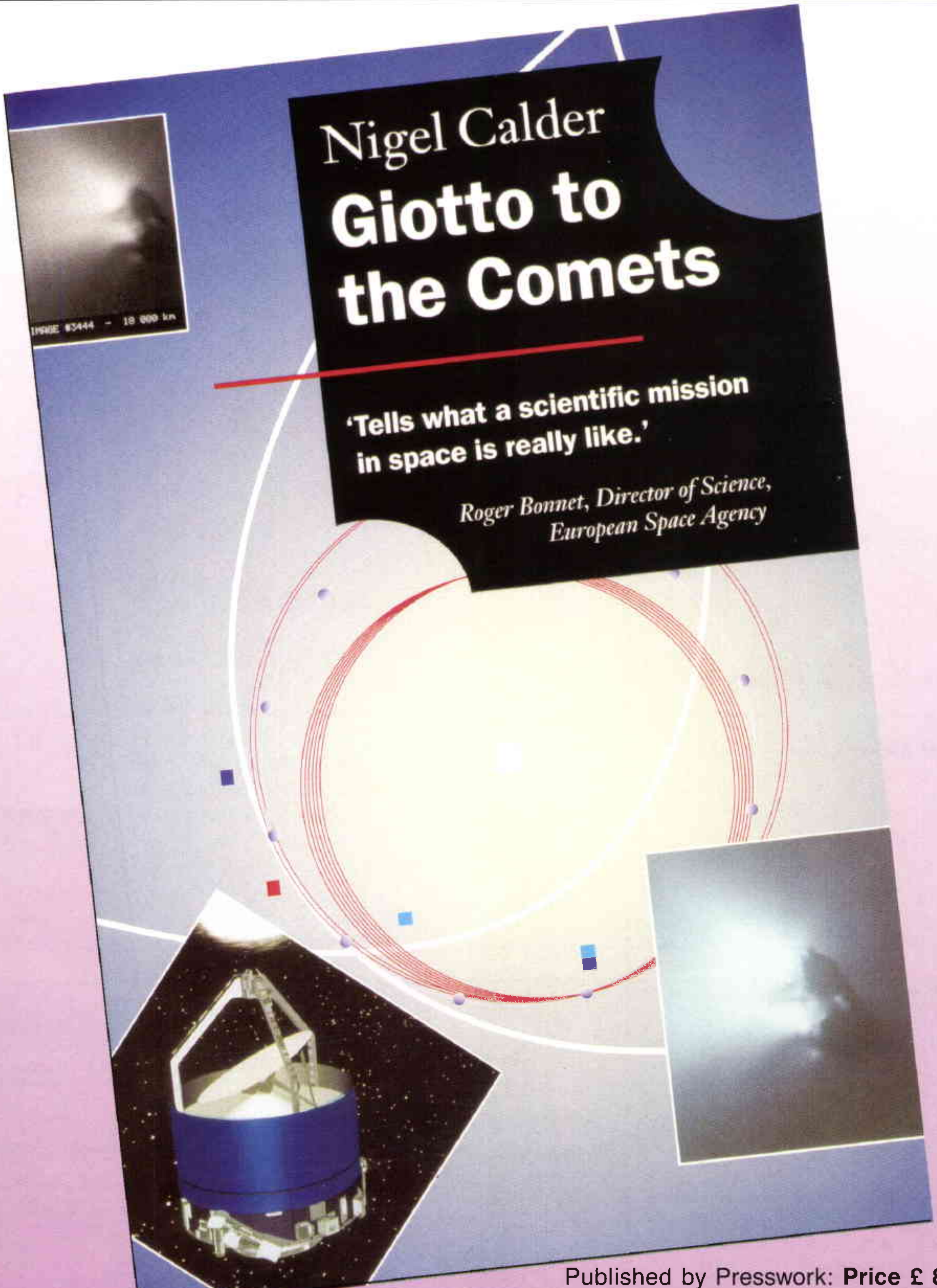
ESA Procedures, Standards and Specifications

ESA PSS-01-301 ISSUE 2 // PRICE 25 DFL
DERATING REQUIREMENTS APPLICABLE TO ELECTRONIC, ELECTRICAL AND ELECTRO-MECHANICAL COMPONENTS FOR ESA SPACE SYSTEMS
ESTEC PRODUCT ASSURANCE & SAFETY DEPARTMENT

ESA PSS-01-721 ISSUE 2 // PRICE 25 DFL
FLAMMABILITY TESTING FOR THE SCREENING OF SPACE MATERIALS
ESTEC MATERIALS & PROCESSES DIVISION

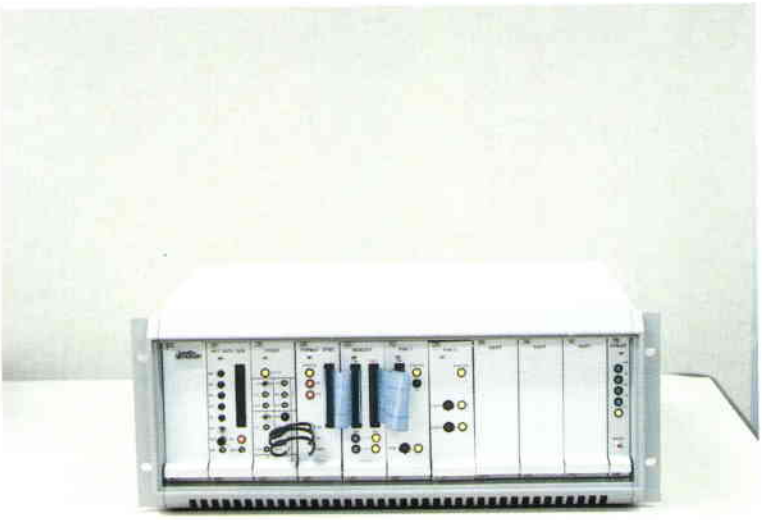
ESA PSS-04-107 ISSUE 2 // PRICE 50 DFL
PACKET TELECOMMAND STANDARD
ESA STANDARDS APPROVAL BOARD (STAB) FOR SPACE DATA COMMUNICATIONS

ESA PSS-07-0 ISSUE 1 // PRICE 25 DFL
GROUND SEGMENT INFRASTRUCTURE STANDARDS
ESA COMMITTEE FOR OPERATIONS AND EGSE STANDARDS (COES)


Nigel Calder
Giotto to the Comets
'Tells what a scientific mission in space is really like.'
Roger Bonnet, Director of Science, European Space Agency

Packet Telemetry Extraction System

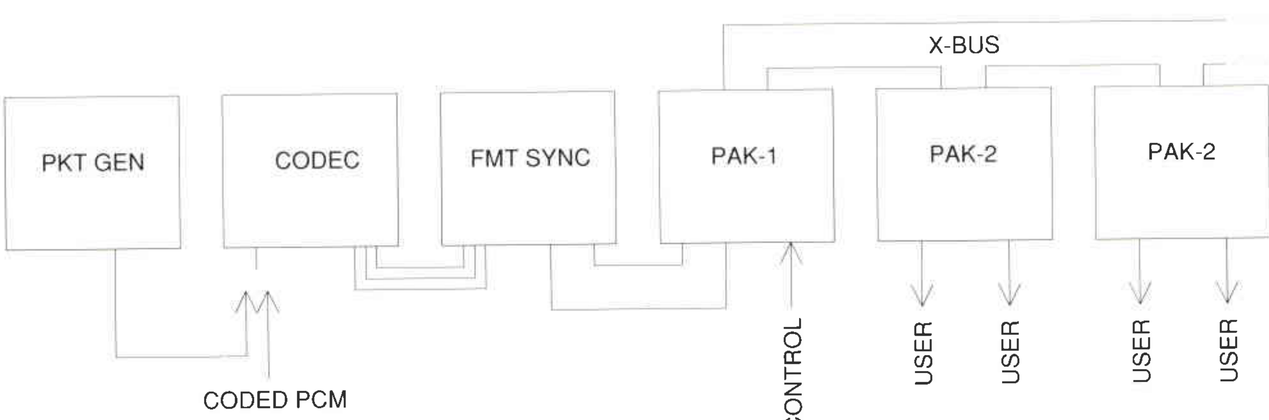
Also available for both VME and PC/AT Systems



The Packet Telemetry Extraction system is a self-contained data decommutation system which contains many original features and performance advantages over its contemporaries. Its unique architecture gives a powerful but extremely flexible system which is readily configurable to different Users' demands and easy to use and maintain.

This multi-processor multi-function system has been designed to provide not only modular growth when required but also not limit the User to specific functions and facilities. With the Packet Telemetry Extraction system the User can meet his current and future requirements exactly. Even more importantly, the flexibility of the Packet Telemetry Extraction system means that increasing throughput requirements can be dealt with without changes in operating system or applications software and without the loss of any system performance during expansion. The bus structure used also allows standby processing and multi-stream data processing to be implemented easily, and with the unique communications link, several units may be linked together giving increased flexibility and processing power.

The Packet Telemetry Extraction system is based upon the T136A and T136B modules from the 'DART' system product range. A simulation module provides a built in test capability for system performance validation and maintenance. Optional modules can be added to provide up to 128 user port.



For further information please contact:
Satellite Services B.V.
Scheepmakerstraat 40
2222 AC Katwijk
The Netherlands
Tel.:(31)(0)1718-28120/28159
Fax:(31)(0)1718-27934

Publications Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Availability	Source
Periodicals				
ESA Bulletin	4	ESA's prime magazine	Free of charge	ESA Publications Division, ESTEC, 2200 AG Noordwijk, The Netherlands
ESA Journal	4	ESA's learned journal	"	
Earth Observation Quarterly (English or French)	4	Remote-sensing newspaper	"	"
ECSL News	4	Newspaper of the European Centre for Space Law (under the auspices of ESA)	"	"
Reaching for the Skies	4	Space Transportation Systems newspaper	"	"
Columbus Logbook	4	Space Station/Columbus newspaper	"	"
Microgravity News (English with French summaries)	3	Microgravity Programme newspaper	"	"
Preparing for the Future	4	Technology Programme newspaper	"	"
News & Views	4	ESA Information Retrieval Service's newspaper	"	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Volumes of specific Conference papers	Prices below	ESA Publications Division, ESTEC, 2200 AG Noordwijk, The Netherlands
Scientific/Technical Monographs	(SP-xxxx)	Specific/detailed information on graduate-level subjects	"	
ESA Brochures	(BR-xxx)	Summaries of less than 50 pages on a specific subject	"	"
ESA Folders	(F-xxx)	'Folders' giving short descriptions of subjects for the space-interested layman	Free of charge	"
Scientific & Technical Reports	(STR-xxx)	Graduate level — reflecting ESA's position on a given subject	Prices below	"
Scientific & Technical Memoranda	(STM-xxx)	Graduate level — latest but not finalised thinking on a given subject	"	"
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of contracts	"	"
Other Publications				
Training Manuals	(TM-xxx)	Series for education of users or potential users of ESA programmes, services or facilities	"	"
Technical Translations	(TT-xxx)	Translations of national space-related documents — (Microfiche or photocopy only)	Prices from ESRIN	ESRIN, Via Galileo Galilei, CP64, 00044 Frascati, Italy, or ESA/IRS Office, 8-10 Mario Nikis 75738 Paris 15, France
Public-relations material		General literature, posters photographs, films, etc		ESA Public Relations Service 8-10 rue Mario-Nikis 75738 Paris 15, France

Charges for printed documents	E0	E1	E2	E3	E4
Number of pages in document:	1—50	51—100	101—200	201—400	401—600
Price (Dutch Guilders)	25	35	50	70	90

Order Form for ESA Publications

IMPORTANT

1. Orders must be accompanied by a Cheque or International Banker's Draft, in Dutch Guilders, made payable to 'ESA Publications Division'. No publications will be sent before receipt of payment. The minimum value order accepted from 1 January 1991 is Dfl 75. (Does not apply to periodicals or folders, which are free of charge).
2. Mailing free-of-charge (sea mail outside Europe). If airmail is required outside Europe, please add 10% to total.

RETURN TO: FINANCE DIVISION (EFA/P)
ESTEC, POSTBUS 299
2200 AG NOORDWIJK
THE NETHERLANDS

No. of copies	ESA reference	Title	Price per copy, Dfl.	Total Dfl.

Airmail (outside Europe)[2] ☐ yes If yes, add 10% of total: ....

MINIMUM ORDER Dfl. 75. Total amount enclosed: Dfl. ....

MAILING ADDRESS (Print carefully)

Name ....

Function ....

Organisation ....

Mailing Address ....

....

Town & Postal Code ....

Country ....

Date .... Signature ....

METHOD OF PAYMENT (Please tick box)

☐ Cheque
☐ International Banker's Draft

enclosed, made payable to ESA Publications Division.

esa
european space agency
agence spatiale européenne

Member States

Austria
Belgium
Denmark
France
Germany
Ireland
Italy
Netherlands
Norway
Spain
Sweden
Switzerland
United Kingdom

Etats membres

Allemagne
Autriche
Belgique
Danemark
Espagne
France
Irlande
Italie
Norvège
Pays-Bas
Royaume-Uni
Suède
Suisse

European Space Agency / Agence Spatiale Européenne
8 - 10 rue Mario-Nikis, 75738 Paris Cedex 15, France